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Enlisted Personnel Allocation System

Interim Progress Report
October 1987-March 1988

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and John Stewart

General Research Corp.

for

Contracting Officer's Representative
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The Army Research Institute, with the assistance of the General Research Corporation, is undertaking a project to modernize and improve the way the Army determines the Military Occupational Specialty (MOS) for which an individual should be trained. This project is called the Development of the Enlisted Personnel Allocation System (EPAS). This report describes progress during the first half of the 7th year of the contract.

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is undertaking a comprehensive research program designed to improve the selection, classification, and allocation of Army personnel. A key part of this program is the Enlisted Personnel Allocation System (EPAS), which will improve personnel performance by achieving a better match between the Army's requirements and the capabilities of the people applying for service. This semiannual report covers the period of October 1987 through March 1988.

ENLISTED PERSONNEL ALLOCATION SYSTEM: INTERIM PROGRESS REPORT

EXECUTIVE SUMMARY

F. 1473

Requirement:

The Army's present person-job-match (PJM) system has substantial opportunities for improvement. These include assigning more enlistees to jobs that maximize their expected performance and minimize their attrition and holding open selected jobs that can attract high-quality applicants. Essential for realizing these improvements is the ability to look ahead at the supply of applicants and the job training requirements.

Procedure:

The authors are developing a prototype decision support system (DSS) that incorporates advanced operations research techniques to improve the Army's person-job-match capabilities. Called the Enlisted Personnel Allocation System (EPAS), it integrates forecasting and large-scale linear optimization. Because of the complexity of this effort, the authors first developed a reduced-scale prototype to evaluate their systems design. The prototype system has been transferred to the National Institutes of Health (NIH) computer facility for more extensive testing and is being enhanced to include additional features based on continuing research and analysis of the PJM process.

Findings:

The prototype system validated the EPAS design concept and demonstrated the feasibility of using this complex DSS to guide Army guidance counselors' classification decisions and to evaluate recruiting strategies. Refinement and testing of EPAS on the NIH computer facility has further demonstrated the capability and flexibility of the system. The EPAS concept represents a significant improvement over current person-job-match systems.

Utilization of Findings:

The present work has provided a sound justification for continuing EPAS research and development. Further experiments should be conducted on current recruiting data for additional refinement of capabilities and assessment of policy alternatives. Plans for porting the EPAS onto an Army computer system for further analysis should proceed. (SDW) <f

ENLISTED PERSONNEL ALLOCATION SYSTEM: INTERIM PROGRESS REPORT

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INTRODUCTION

The Army Research Institute (ARI) is sponsoring a major research effort to improve "the selection, classification, and utilization of Army enlisted personnel." The underlying approach associated with the required research has been divided into two major projects:

Project A -- the development and validation of improved selection and classification instruments and standards.

Project B -- development of a prototype computerized personnel allocation system

The second of these projects, Project B, was awarded to the General Research Corporation (GRC) in September of 1982. The major objective of Project B is to:

"...develop a prototype system to link personnel resources to Army requirements in ways which will optimize the total effectiveness of the Army. This research should yield a set of operational, computer-assisted, decision aids for military personnel actions. ... The research will build on the state-of-the-art in such areas as: differential classification of people/jobs, prediction of employee work behavior, optimization, algorithms, methods of combining multiple objectives, and estimation of utility or pay-off equations as used in (or planned for) the Air Force preenlistment, person-job match system." (Statement of Work, pg. 2)

GRC has developed the Enlisted Personnel Allocation System (EPAS) to meet the requirements of the contract.

Organization of Report

GRC continues to conduct extensive research and analysis to determine the best technique for the development of a system concept to implement the desired optimization capabilities. This report documents GRC's research pursuant to this contract effort covering the reporting period through April, 1988. The report contains the following sections:

I A general introduction to the report.

II A detailed discussion of the techniques and continuing analysis used to define the Supply Groups used by EPAS.

III A discussion of the current system (the Active Army Search) with an analysis of the effort necessary to provide a simulation capability of the current system as well and to integrate EPAS into the current system.

IV An overview of progress since the last reporting period.

Statement of Problem

The Army routinely processes approximately 140,000 non-prior service (NPS) applicants each year. In theory, each of these applicants could be eligible for approximately 6,000 MOS/training start dates, resulting in some 840 million possible combinations. Army policy requires that the Military Occupational Specialty (MOS) in which each new recruit is to be trained be determined at time of enlistment. The applicant/MOS classifications made at this time have significant impact in such areas as:

- o Recruiting effectiveness
- o Force readiness
- o Soldier performance
- o Retainability

Making these classification decisions effectively and efficiently requires an understanding of the relationship of an individual's characteristics to probable performance in the Army in some specific MOS. This, in turn, requires both the ability to quantify this relationship and the means to systematically apply this knowledge. There is an ever-present need to improve and extend both the validity and the effectiveness of the Army's classification process.

In the current Army process, volunteers take the Armed Services Vocational Aptitude Battery (ASVAB). This test produces scores that are used to determine if the applicant meets the <u>minimum</u> eligibility for MOS. The Army's current classification methodology, part of the REQUEST system, uses these test scores to eliminate MOS for which the applicant is not qualified. The remaining MOS are then processed to generate an ordered list of jobs which the Army would like the applicant to consider. This process, details of which are described in Appendix A, places primary emphasis on the need to fill vacant training seats within the time window being examined; virtually no emphasis is placed on predicting the applicant's performance in the MOS being considered.

This current process does not "look ahead" in any significant manner to consider future impacts or alternatives. It can not, therefore, address personnel factors such as:

- o What is the effect of filling a training seat with a minimally qualified volunteer?

- o What is the impact of deliberately leaving a training seat empty?

- o What is the probability that a person who is "better" qualified than the current applicant will become available to fill some specific training seat?

- o What contribution will some specific person-job match make to the applicant's performance in the initial entry skill?

It is important to note the sequential nature of the current process. The Army must consider volunteers in the order in which they arrive for processing. It is unrealistic to assume some system will control the actual arrival sequence of applicants.

Instead, the design criterion of this contract specifies the design and validation of a system concept which can be used to "optimally" make the decision about which MOS the Army would like applicants to serve in. The guidance provided by such a system would represent a changing definition based on real-time assessments of training requirements and anticipated applicant arrivals. Use of this system would place applicants where they can be expected to perform to their maximum potential, within the policy restrictions and mission requirements of the Army.

SUPPLY GROUP FORMULATIONS

The contract specifications for EPAS included supply forecasting as one of its desired system capabilities. Its importance was reiterated when the statement of work listed as a key problem: "the determination of a reasoned guess about the number and kind of people likely to be available for recruitment into the Army during some specific week, month or year". It was therefore decided early on to build a supply forecasting capability into EPAS. Because of the many existing forecasting methodologies and the expectation for new models to be developed, we decided to design/build into EPAS the capability for multiple forecasting models and for the easy integration/operation of additional models.

A related problem, which wasn't taken into account in the statement of work but which became essential to the development of EPAS, was the necessity to aggregate the supply. The Army's non-prior service assignment problem is unique in its size and complexity. Typically, 140,000 individuals contract each year for training seats in approximately 270 MOS. The total number of training classes available during the year is approximately 6000. Without considering the eligibility restrictions, this gives 840,000,000 possible assignments. A problem of this magnitude could not be solved on existing computer hardware and software.

Our approach was to aggregate the supply of contractees into categories called Supply Groups and to aggregate the jobs (MOS) into groups called MOS Clusters. Both categorizations were based on demographic and performance characteristics, since this supported the Army's person-job assignment problem. Two formulations hvae been developed and implemented during the project. The formulation currently being used generates 81 Supply Groups and 89 MOS Clusters. With this configuration, we were able to reduce the assignment problem to 86508 (81x89x12 months) possible assignments; a much more workable problem.

This paper covers the development of Supply Groups. In it, we provide insight into the technical problems that exist, how we decided on a solution, and suggestions for future developments. The following six functional areas are discussed:

- Review the Army's recruit missioning process.
- Aggregate the supply population.
- Review clustering techniques.
- Compute subpopulation statistics.
- Evaluate and select clustering methodology.
- Define areas of future work.

Review the Army's Recruit Missioning Process

The Army currently states its requirements for recruits as "missions" grouped by gender, education level, and categories based on the Armed Forces Qualification Test (AFQT):

- o Gender - male or female.
- o Education level.
  - high school diploma graduate.
  - high school senior.
  - less than high school graduate.
- o AFQT Category.
  - I for AFQT 93-99.
  - II for AFQT 65-92.
  - IIIA for AFQT 50-64.
  - IIIB for AFQT 31-49.
  - IV for AFQT 16-30.
  - V for AFQT less than 16[1]

Various limits and goals are set on enlistee quality by Congress, the Department of Defense, and the Army. Examples of the times of limits which are imposed include:

- o Congressional limits on the number of recruits in AFQT Category IV.
- o Army goals are established by MOS for the desired number of AFQT Categories I-IIIA.
- o Seniors can't be assigned to a MOS until after graduation.
- o Women are restricted from MOS with combat requirements.

Quality Goals

Aggregate accession requirements are generated by the Office of the Deputy Chief of Staff for Personnel (ODCSPER) with the use of the Enlisted Loss Inventory Model and the Computation of Manpower Programs using Linear Programming (ELIM-COMPLIP) System. This system minimizes the differences between established trained strength objectives and

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[1]AFQT Category V personnel are not eligible for military service under current policy. Their definition is included here for completeness.

actual strength forecasts, and incorporates a number of constraints such as total Army training capacities.

An overall goal for quality recruits (i.e., male, high school graduates in AFQT Categories I-IIIA) is established by congress. Army manpower planners review the aggregate accession requirements, the skill requirements for each job, and the career force requirements for each MOS. Quality goals are then established for every entry level MOS so that the overall quality goal is maintained.

The Recruiting Accession Requirement

ELIM-COMPLIP accession requirements are on a calendar month basis. The U.S. Army Recruiting Command's (USAREC) goaling, however, is done on a Reception Station Month (RSM) basis. A RSM consists of either four or five 7-day weeks that begin on Tuesday and end on Monday. The RSM concept ties the recruiting program to the start of training. It also smooths the peaks and valleys of recruit arrival at the training bases by eliminating the potential for large increases in accessions at the end of the calendar month. The U.S. Army Recruit Command (USAREC) converts calendar month accession requirements into RSM accessions objectives on a quarterly basis.

USAREC apportions the recruiting missions to the District Recruiting Battalions, formerly referred to as Commands, on a recruit station month (RSM) basis. These apportionments--the recruiting mission-- define the number and type of personnel to be recruited on a monthly basis.

The Delayed Entry Program

A contract is signed by the recruit when the oath of military service is administered and a training seat reserved. An accession is defined as the point when an individual arrives at a reception station to begin basic training.

The Army's Delayed Entry Program (DEP) provides the recruit with the opportunity to delay the accession date until some period of time following the signing of the contract. The exact length of time which an individual may delay entry is controlled by the Army so as to best meet its recruiting and accession goals.

EPAS must be concerned with both the contract date and the accession date. The contract date is the point at which the enlist/do-not-enlist decision is made by the recruit and an MOS is assigned. Since EPAS is to provide recommendations to assist both the Army and the recruit find the optimal person-job match, it must be able to make its recommendations based on the characteristics of the Army at the time the recruit is available for signing a contract.

The accession date defines when the applicant actually enters the Army. This, in turn, defines when an applicant will complete training. EPAS must use this information to insure that both the ELIM-COMPLIP monthly accession plan is meet and that the annual training program for each MOS is achieved.

Aggregating the Supply Population

As discussed in the introduction, to handle the size and complexity of the Army's assignment process, EPAS uses aggregated supply and MOS in its design. The supply aggregation had to meet two requirements:

- It must allow the system to maintain its ability to implement Army policy restrictions and guidelines,
- It must maintain the system capability to predict an applicant's performance in a MOS.

The supply could have been partitioned using one of three approaches, specifically:

- First break the supply into groups based on their demographic characteristics, then cluster based on predicted performance.
- First aggregate the supply into similarly performing subpopulations and then breaking these down into their demographic components.
- A non-nesting or cross factors approach, where the supply is aggregated into subpopulations based on all combinations of both dimensions, aptitude areas and demographic categories.

The first options was selected as the technique which best met the two requirements for supply aggregation.

Implementing Policy

Categorizations of the populations were superimposed to split the total population into distinct subpopulations. This categorization was performed based on the following demographic categories:

- Gender -- male (M) and female (F).
- Education -- high school graduates (HSG), high school seniors (HSS), and non-graduates (NG).
- Armed Forces Qualification Test (AFQT) Score -- categories I-IIIA, IIIB, and IV.

This resulted in 20 distinct subpopulations which are depicted in Table 1. These subpopulations allow the system to goal for standard policies such as female exclusion from combat skills, quality goals, and education requirements.

Performance Prediction

Next, each of twenty subpopulations were clustered based on a factor which would predict the probable performance of the applicants. The present formulation uses the Army's current definition of performance, the Aptitude Area Composite score, as the basis for its clustering.

The Army uses groups its initial entry MOS into nine aptitude areas. Table 2 gives the aptitude areas and the major jobs in the Army associated with each. Composites of the ASVAB subtests are used to generate a score within each of the nine aptitude areas. The score for an aptitude area provides an indication of the applicant's expected performance for all MOS within that aptitude area.

Cluster analysis was used to develop these Supply Groups. A review of available techniques was conducted, after which a preliminary analysis was done to determine to select the clustering approach which best suited the EPAS requirements.

Review Clustering Techniques

The aim of clustering techniques is to develop groups (clusters) of similar individuals or objects. These techniques have been used and developed in many fields, including statistics, biology, and psychology. Their range of complexity goes from the simple intuitive approaches to the complex graph theoretic and probabilistic models.

A "similarity criterion", as its name suggests, is used to measure how alike two objects or individuals are. It is a single-valued function of those characteristics which are used to determined likeness, e.g. aptitude area composite scores. Some common criteria, stated in terms of these measures, are:

- Euclidean criterion or metric, where the measure of similarity of two individuals is the square root of the sum of squared differences in the aptitude area composites.
- City-block criterion or metric, where the similarity is based on the sum of absolute differences in the respective composites.
- Standard correlation coefficient.

Table 1

Supply Subpopulations Based on Mission Categories[2]

NO. NO.	GENDER GENDER	EDUCATION LEVEL	AFQT CATEGORY	% FY84 SUPPLY	% FY86 SUPPLY
1	M	HSG	I-II	20.9	25.0
2	M	HSG	IIIA	10.7	15.8
3	M	HSG	IIIB	19.6	22.9
4	M	HSG	IV	11.2	4.4
5	M	HSS	I-II	3.4	3.3
6	M	HSS	IIIA	2.4	2.6
7	M	HSS	IIIB	4.8	2.8
8	M	HSS	IV	.5	.1
9	M	NHS	I-II	4.1	3.4
10	M	NHS	IIIA	4.9	5.6
11	M	NHS	IIIB	3.5	.4
12	M	NHS	IV	1.0	<.1
13	F	HSG	I-II	4.3	4.8
14	F	HSG	IIIA	3.1	4.1
15	F	HSG	IIIB	4.3	4.1
16	F	HSG	IV	.3	<.1
17	F	HSS	I-II	.4	.3
18	F	HSS	IIIA	.4	.3
19	F	HSS	IIIB	.2	.1
20	F	HSS	IV	<.1	<.1
TOTAL				100.0	100.0

[2]The data used for these analyses does not correctly distinguish between high school seniors and high school graduates at the time when the contract was signed. The data and figures shown throughout this report are included to demonstrate the methodological approach. Additional research is now being performed to identify sources for valid data. Once corrected data becomes available, all supply groups will be regenerated using the procedures described in this report.

Table 2
Composition of Aptitude Areas

APTITUDE AREA	MAJOR JOBS IN EACH APTITUDE AREA
CL (Clerical)	Administrative, Supply, Finance
CO (Combat)	Infantry, Armor, Combat Engineer
EL (Electronics Repair)	Missiles Repair, Air Defense Repair, Electronics Repair, Fixed Plant Communications Repair
FA (Field Artillery)	Field Cannon and Rocket Artillery
GM (General Maintenance)	Construction and Utilities, Marine, Chemical, Petroleum
MM (Mechanical Maintenance)	Mechanical and Aircraft Maintenance, Rails
OF (Operators and Food)	Missiles Crewmen, Air Defense Crew, Driver, Food Services
SC (Surveillance and Communications)	Target Acquisition and Combat Surveillance, Communications Operations
ST (Skilled Technical)	Medical, Military Police, Intelligence, Data Processing, Air Control, Topography and Printing, Information and Audio Visual

Most clustering algorithms can be classified as either hierarchical or nonhierarchical. Hierarchical methods seek to produce a set of nested clusters ranging from one cluster containing all the objects to many clusters where each contain only one object. These methods can be further classified as either agglomerative or divisive approaches.

Agglomerative algorithms start with each individual or object as a cluster, and proceed by a series of pairwise mergings of these objects until one cluster containing all the objects is derived. Divisive methods begin with all the objects or individuals as part of one cluster, and proceed by a series of successive splittings until a set of many clusters with one object in each is obtained.

In one of our Supply Group formulations, we selected an agglomerative hierarchical clustering procedure, the Ward's minimum variance approach, which is available as an option to the SAS procedure CLUSTER. With this approach, the distance between two clusters is the analysis of variance (ANOVA) sum of squares between the two clusters taken over all of the clustering variables (the nine aptitude area composite scores). At each step in the cluster generation, the two clusters which give the smallest increase in the within-cluster variablity are joined. This is continued until one cluster is obtained.

In nonhierarchial cluster analysis, the number of clusters is assumed to be known beforehand. The objective is to find the clusters. Some of the more common of these approaches are:

- o Nearest centroid sorting.
- o Hill climbing.
- o Mode seeking or density search.

For our Supply Groups, we have implemented a nearest centroid sorting algorithm (SAS procedure FASTCLUS). Its basic algorithm for finding "g" clusters, where "g" is a prespecified number, is as follows:

- o Choose a set of cluster seeds as an initial guess to the cluster means.
- o Form clusters by assigning each observation to the closest seed. FASTCLUS uses the Euclidean metric to determine closeness.
- o Compute the cluster means, and use them as the the next generation of cluster seeds. Repeat step 2 until the changes in the seeds become small.
- o Reassign all of the observations to this final set of cluster seeds. This is the final clusters.

Hill-climbing approaches start with an initial partition generated by some type of nearest centroid algorithm and then entities are reallocated on the basis of improving some preselected criterion function. Some of the criteria used include minimizing the trace of the pooled within-groups scatter matrix or minimizing its determinant.

Mode-seeking algorithms include the mixture model approach. A mixture model assumes that the data is a random sample from a mixture of distributions. The objective is to estimate the parameters of the component distributions and the mixing parameters.

For our Supply Group formulations, we selected two approaches, a nearest centroid sorting algorithm and Ward's minimum variance method. This selection was based on the intuitive appeal of their algorithms and their ability to create differential groups. Time limitations prohibited an extensive evaluation of the many available techniques.

Compute Subpopulation Statistics

The effectiveness of most clustering techniques, especially the parametric approaches, are affected by the correlation structure of the variables being studied. Table 3 contains the correlations for the FY86 contract population listed by demographics. There is considerable correlation in the aptitude area composites. The correlation structures are quite similar even across gender and education. (The female, high school graduate, AFQT Category IV subpopulation was not analyzed due to the small number of individuals. This group is typically not even recruited.) We decided the differences were not significant enough to warrant using different clustering algorithms for each of the subpopulations.

Table 4 contains the aptitude area composite averages and standard deviations by demographic group; Table 5 summarizes the same statistics. Even though some of the categories are not that different, notably the high school graduate and senior groups, EPAS maintains them separately in its supply forecasts to allow simulating different policy guidelines based on the demographics. Additionally, the variability in the composites tend to be different across aptitude areas but approximately the same across demographic groups, suggesting the same algorithm could be applicable for all the demographic groups.

Table 3
FY86 Correlations of Aptitude Area Composites

M/HSG/I-II

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.5	.8	.8	.6	.4	.4	.6	.8
CO		1.	.6	.8	.7	.8	.8	.9	.6
EL			1.	.7	.9	.7	.6	.7	.9
FA				1.	.6	.6	.6	.6	.7
GM					1.	.8	.7	.8	.8
MM						1.	.9	.9	.6
OF							1.	.9	.7
SC								1.	.7
ST									1.

F/HSG/I-II

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.6	.8	.8	.7	.4	.4	.6	.8
CO		1.	.6	.8	.7	.8	.8	.9	.7
EL			1.	.7	.9	.7	.6	.7	.9
FA				1.	.6	.6	.6	.7	.8
GM					1.	.8	.7	.8	.9
MM						1.	.9	.9	.7
OF							1.	.9	.7
SC								1.	.8
ST									1.

M/HSG/IIIA

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.8	.7	.5	.1	.1	.4	.6
CO		1.	.5	.7	.6	.8	.8	.8	.5
EL			1.	.6	.9	.5	.3	.6	.8
FA				1.	.4	.4	.3	.5	.5
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.5
OF							1.	.8	.5
SC								1.	.7
ST									1.

F/HSG/IIIA

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.8	.7	.5	.1	.0	.4	.6
CO		1.	.4	.8	.4	.7	.7	.8	.4
EL			1.	.5	.9	.5	.2	.5	.8
FA				1.	.4	.4	.3	.4	.5
GM					1.	.7	.5	.7	.8
MM						1.	.9	.7	.5
OF							1.	.8	.5
SC								1.	.7
ST									1.

M/HSG/IIIB

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.4	.7	.7	.5	.2	.2	.5	.6
CO		1.	.5	.7	.6	.8	.8	.8	.5
EL			1.	.6	.9	.6	.4	.6	.8
FA				1.	.4	.4	.4	.4	.5
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.5
OF							1.	.8	.6
SC								1.	.7
ST									1.

F/HSG/IIIB

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.2	.7	.6	.4	.0	.0	.3	.5
CO		1.	.3	.7	.3	.6	.6	.7	.2
EL			1.	.4	.8	.4	.1	.4	.6
FA				1.	.2	.3	.2	.3	.3
GM					1.	.6	.4	.5	.7
MM						1.	.8	.6	.3
OF							1.	.7	.5
SC								1.	.6
ST									1.

M/HSG/IV

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.2	.6	.5	.4	.0	.1	.3	.5
CO		1.	.3	.7	.5	.7	.7	.8	.3
EL			1.	.4	.8	.4	.2	.5	.7
FA				1.	.1	.3	.2	.2	.2
GM					1.	.7	.6	.7	.7
MM						1.	.9	.7	.4
OF							1.	.8	.5
SC								1.	.6
ST									1.

F/HSG/IV

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	-.1	.6	.3	.4	-.4	-.4	.2	.5
CO		1.	.1	.7	.2	.6	.5	.6	.1
EL			1.	.4	.8	.1	-.2	.3	.7
FA				1.	.2	.3	.2	.3	.2
GM					1.	.4	.2	.4	.8
MM						1.	.8	.3	.1
OF							1.	.5	.2
SC								1.	.5
ST									1.

Table 3 (continued)
FY86 Correlations of Aptitude Area Composites

M/HSS/I-II

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.5	.8	.8	.6	.3	.4	.6	.8
CO		1.	.6	.8	.7	.8	.8	.9	.6
EL			1.	.7	.9	.6	.5	.7	.9
FA				1.	.5	.5	.5	.6	.7
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.6
OF							1.	.9	.6
SC								1.	.7
ST									1.

F/HSS/I-II

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.6	.8	.8	.7	.5	.5	.7	.8
CO		1.	.7	.9	.7	.8	.8	.9	.7
EL			1.	.7	.9	.7	.6	.7	.9
FA				1.	.6	.6	.7	.7	.7
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.7
OF							1.	.9	.8
SC								1.	.8
ST									1.

M/HSS/IIIA

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.8	.7	.5	.1	.1	.4	.7
CO		1.	.5	.7	.6	.8	.8	.8	.5
EL			1.	.6	.9	.5	.3	.6	.8
FA				1.	.4	.4	.3	.5	.6
GM					1.	.8	.6	.8	.8
MM						1.	.9	.8	.5
OF							1.	.8	.5
SC								1.	.7
ST									1.

F/HSS/IIIA

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.4	.7	.7	.5	.1	.1	.4	.6
CO		1.	.4	.8	.4	.7	.6	.7	.4
EL			1.	.5	.9	.5	.2	.5	.7
FA				1.	.3	.4	.3	.5	.5
GM					1.	.6	.5	.6	.8
MM						1.	.8	.6	.5
OF							1.	.7	.5
SC								1.	.7
ST									1.

M/HSS/IIIB

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.4	.7	.7	.5	.2	.2	.5	.7
CO		1.	.5	.7	.6	.8	.8	.8	.5
EL			1.	.6	.9	.6	.4	.6	.8
FA				1.	.4	.4	.4	.5	.5
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.6
OF							1.	.8	.6
SC								1.	.7
ST									1.

F/HSS/IIIB

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.7	.6	.6	.2	.2	.5	.7
CO		1.	.3	.8	.4	.6	.6	.8	.5
EL			1.	.5	.9	.5	.3	.6	.8
FA				1.	.3	.4	.3	.6	.5
GM					1.	.7	.6	.7	.9
MM						1.	.9	.7	.6
OF							1.	.8	.7
SC								1.	.8
ST									1.

M/HSS/IV

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.2	.7	.5	.3	.0	-.1	.2	.4
CO		1.	.4	.8	.5	.8	.8	.8	.4
EL			1.	.5	.8	.4	.2	.4	.7
FA				1.	.3	.4	.3	.5	.3
GM					1.	.8	.6	.7	.8
MM						1.	.9	.8	.5
OF							1.	.8	.5
SC								1.	.6
ST									1.

F/HSS/IV

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL									
CO	No observations								
EL									
FA									
GM									
MM									
OF									
SC									
ST									

Table 3 (continued)
FY86 Correlations of Aptitude Area Composites

M/NHS/I-II

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.4	.8	.8	.6	.3	.3	.5	.8
CO		1.	.5	.8	.7	.8	.8	.9	.6
EL			1.	.7	.9	.6	.5	.7	.9
FA				1.	.5	.5	.5	.6	.7
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.6
OF							1.	.9	.6
SC								1.	.7
ST									1.

M/NHS/IIIA

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.7	.7	.5	.1	.1	.4	.6
CO		1.	.5	.7	.6	.8	.8	.8	.5
EL			1.	.6	.9	.5	.4	.6	.8
FA				1.	.4	.4	.4	.5	.5
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.5
OF							1.	.8	.5
SC								1.	.7
ST									1.

M/NHS/IIIB

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.3	.7	.6	.5	.2	.2	.4	.6
CO		1.	.5	.7	.6	.8	.8	.8	.4
EL			1.	.5	.9	.6	.4	.6	.8
FA				1.	.3	.5	.4	.4	.4
GM					1.	.8	.7	.8	.8
MM						1.	.9	.8	.5
OF							1.	.9	.6
SC								1.	.7
ST									1.

M/NHS/IV

AA	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.	.7	.2	.7	.5	.5	.7	.7	.6
CO		1.	.1	.9	.5	.7	.9	.9	.5
EL			1.	.2	.8	.6	-.1	-.1	.3
FA				1.	.4	.7	.6	.6	.3
GM					1.	.8	.5	.5	.8
MM						1.	.6	.6	.5
OF							1.	1.	.7
SC								1.	.7
ST									1.

Table 4
FY86 Population Statistics by Demographic Group

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
1	M	NHS	I-II	4241	115	119	116	116	115	117	118	120	116	117	2
					7	9	9	9	11	10	7	8	9	9	1
2	M	NHS	IIIA	7127	104	111	105	106	107	110	111	112	106	108	3
					6	9	8	8	11	10	7	8	8	8	1
3	M	NHS	IIIB	542	99	107	100	101	102	106	106	106	101	103	3
					6	10	8	8	11	10	8	9	9	9	2
4	M	NHS	IV	10	87	95	90	90	94	97	95	93	89	92	3
					5	13	7	8	9	6	8	12	6	8	3
5	M	HSG	I-II	31674	120	122	121	121	120	120	120	122	121	121	1
					8	9	10	9	11	10	8	8	9	9	1
6	M	HSG	IIIA	19965	107	111	108	108	109	110	110	111	108	109	2
					6	9	9	8	11	10	8	9	9	9	1
7	M	HSG	IIIB	28976	95	102	96	98	98	102	101	100	96	99	2
					7	10	9	8	11	10	8	10	9	9	1
8	M	HSG	IV	5537	87	97	89	93	92	97	94	92	89	92	3
					5	9	8	7	10	9	7	8	8	8	1
9	M	HSS	I-II	4127	119	118	120	119	118	116	117	119	120	118	1
					7	9	9	9	10	10	7	8	8	9	1
10	M	HSS	IIIA	3309	107	110	108	109	108	109	109	110	109	109	1
					6	9	9	8	11	10	7	8	8	8	1
11	M	HSS	IIIB	3536	96	101	98	99	100	102	101	100	99	100	2
					7	10	9	8	11	10	8	9	9	9	1
12	M	HSS	IV	171	89	96	91	93	93	96	94	94	92	93	2
					5	10	8	8	10	11	9	8	8	8	2
13	F	HSG	I-II	6026	117	112	112	117	106	105	110	110	113	111	4
					8	10	10	10	11	10	8	9	10	9	1
14	F	HSG	IIIA	5129	104	100	99	104	94	95	100	98	100	99	4
					6	8	8	8	9	8	6	7	8	8	1
15	F	HSG	IIIB	5200	95	94	91	97	87	90	93	90	92	92	3
					6	8	7	8	8	7	6	7	7	7	1
16	F	HSG	IV	100	88	90	86	92	84	87	88	84	86	87	3
					6	8	7	7	7	7	6	6	7	7	1
17	F	HSS	I-II	408	117	110	112	117	105	103	108	108	113	110	5
					7	9	9	10	10	9	7	8	9	9	1
18	F	HSS	IIIA	405	105	100	100	105	95	95	100	98	102	100	4
					6	8	8	9	9	7	6	7	8	7	1
19	F	HSS	IIIB	59	98	96	95	100	90	92	95	92	96	95	3
					6	9	8	9	10	7	7	8	10	8	1
20	F	HSS	IV	8	93	89	90	93	86	88	89	86	89	89	3
					2	6	7	6	6	4	6	5	5	5	2

Table 5
FY86 Contractee Population Statistics

TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
126567	107	110	107	108	107	108	109	109	107	108	1
	13	13	14	13	15	13	12	13	14	13	1

Evaluate and Select Clustering Methodology

The goal was to develop Supply Groups which would preserve the "aggregate" differentiable performance characteristics exhibited by the individual recruits. We clustered the individuals in each demographic subpopulation using the aptitude area composite scores as the clustering variables. The average aptitude area composites were then used as the performance measures for each of the Supply Groups.

Research issues included evaluating which clustering algorithm to use and determining whether it should be applied to the individual performance measures or a function of them. We developed and implemented two approaches. The first approach used a nearest centroid sorting algorithm to cluster a function (principal components) of the aptitude area composites (see Final Report, October, 1986 - September, 1987). The second used Ward's minimum variance method to cluster the nine aptitude area composites. The latter one is described in detail below.

Supply Groups using Wards' Clustering Algorithm

Early in 1987, we started an effort to improve our supply group definitions by increasing their differentiablity. A new approach was taken to deal with the high intercorrelations in the aptitude area composites. Instead of clustering on a function of these scores, i.e. the first principal component, we clustered on all nine of the composites. A different clustering methodology was implemented, one designed to utilize the correlation structure in its algorithm. In addition, the determination of the number of supply groups per subpopulation was changed to be based on the subpopulation size. These changes resulted in an increase in the total number of supply groups to 81. The FY86 supply population was used for this development.

The FY 86 supply exhibited high intercorrelations in its aptitude area composites (Table 3). We elected to use the Ward's minimum variance approach, a clustering algorithm which would take advantage of the high intercorrelations. This algorithm, which was used in conjunction

with a nearest centroid sorting approach, develops clusters by minimizing the within-cluster variability. The actual clustering procedure, performed for each subpopulation, was:

- Use a nearest centroid sorting routine (SAS procedure, FASTCLUS) to generate a large number (typically 100) of preliminary clusters.

- Remove those clusters (outliers) which have a relatively small (less than 30) number of individuals.

- Using the same nearest centroid algorithm, regenerate another large set of clusters using the clusters from (2) as the starting point.

- Apply Ward's algorithm to this last set of clusters, weighting each of these clusters by their size, to get the desired number of clusters (Supply Groups) for this subpopulation.

There were no observations for female, high school senior, AFQT Category IVs. The female, high school senior, AFQT Category IIIB subpopulation was truncated at AFQT score 40 and above to provide an estimate of this population. Even though this particular mission is not goaled, it is necessary that EPAS be able to account for the characteristics of this group for policy analysis.

Table 6 lists these Supply Groups along with their aptitude area composite averages (AVG) and standard deviations (SD).

Observations

To evaluate how well these supply group differentiated the supply, we computed the between-group and within-group aptitude area variablities (standard deviations) and their corresponding ratios for each subpopulation. These data are shown in Table 7. With average ratios of around two and with within group variability typically less than five, this algorithm produced relatively disjoint and compact Supply Groups for the male, high school graduates, AFQT Categories I-II, IIIA, and IIIB subpopulations. It did not perform quite as well for some of the lower quality categories.

Another measure of the effectiveness is the magnitude of each subpopulation's average supply group variability relative to the subpopulation's variability. Table 8 expresses this as a percentage change in the subpopulation variability. Average values ranged from 20% to 57% reduction in variability. (For those subpopulations with only one supply group the standard deviation is the same for both, and hence a 0% reduction in variability).

Table 6

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
1	M	NHS	I-II	2352	113	117	114	113	113	116	117	118	114	115	2
					6	6	7	7	6	6	5	5	6	6	1
2	M	NHS	I-II	1313	121	128	125	123	126	127	125	128	124	125	2
					6	5	6	6	6	5	4	4	5	5	1
3	M	NHS	I-II	576	109	107	104	108	99	103	107	107	105	105	3
					5	7	5	7	6	6	5	5	6	6	1
	M	NHS	I-II	4241	115	119	116	116	115	117	118	120	116	117	2
					7	9	9	9	11	10	7	8	9	9	1
4	M	NHS	IIIA	638	99	96	93	96	88	94	98	96	93	95	3
					5	6	6	6	6	6	5	4	5	5	1
5	M	NHS	IIIA	2845	102	107	101	103	101	106	108	108	102	104	3
					5	7	5	6	6	6	5	5	6	6	1
6	M	NHS	IIIA	2030	105	114	108	107	110	114	113	115	109	111	4
					6	7	5	7	4	6	6	5	5	6	1
7	M	NHS	IIIA	1614	109	119	115	112	120	120	117	120	115	116	4
					5	6	5	6	5	6	4	5	5	5	1
	M	NHS	IIIA	7127	104	111	105	106	107	110	111	112	106	108	3
					6	9	8	8	11	10	7	8	8	8	1
8	M	NHS	IIIB	542	99	107	100	101	102	106	106	106	101	103	3
					6	10	8	8	11	10	8	9	9	9	1
	M	NHS	IIIB	542	99	107	100	101	102	106	106	106	101	103	3
					6	10	8	8	11	10	8	9	9	9	2
9	M	NHS	IV	10	86	95	91	90	95	98	96	93	90	93	4
					6	14	6	9	8	6	8	11	6	8	3
	M	NHS	IV	10	87	95	90	90	94	97	95	93	89	92	3
					5	13	7	8	9	6	8	12	6	8	3

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVE	STD
10	M	HSG	I-II	1239	109	102	103	105	97	99	104	103	103	103	3
					5	6	6	6	7	6	5	5	5	6	1
11	M	HSG	I-II	1649	116	109	111	114	105	104	107	108	111	109	4
					5	6	5	7	6	5	4	4	5	5	1
12	M	HSG	I-II	1091	109	114	104	110	103	110	114	113	107	109	4
					4	5	3	7	5	4	3	3	5	4	1
13	M	HSG	I-II	1323	122	113	119	121	112	106	109	112	118	115	6
					3	4	4	4	4	4	4	4	4	4	0
14	M	HSG	I-II	1823	115	111	115	111	114	112	113	113	115	113	2
					4	4	4	5	5	4	3	3	4	4	1
15	M	HSG	I-II	1148	108	118	108	111	111	118	119	118	109	113	5
					4	4	4	5	4	4	3	3	4	4	1
16	M	HSG	I-II	2172	119	119	117	120	114	114	116	119	118	117	2
					4	3	4	4	4	3	3	3	4	4	1
17	M	HSG	I-II	1250	111	126	111	117	113	123	123	123	112	118	6
					4	4	4	5	5	5	4	3	4	4	1
18	M	HSG	I-II	2160	125	122	124	127	119	116	118	121	125	122	4
					3	4	3	4	5	4	3	4	4	4	1
19	M	HSG	I-II	2827	130	135	135	134	137	135	132	134	133	134	2
					3	4	3	5	3	3	3	2	3	3	1
20	M	HSG	I-II	2091	128	124	131	128	128	121	120	124	129	126	4
					3	4	3	6	4	4	3	3	3	4	1
21	M	HSG	I-II	1898	123	128	124	127	124	124	124	126	124	125	2
					3	4	3	4	3	3	3	3	4	3	1
22	M	HSG	I-II	1848	119	123	120	121	121	122	121	122	120	121	1
					3	4	4	4	5	3	3	3	4	4	1
23	M	HSG	I-II	1865	113	118	118	112	121	122	120	121	117	118	4
					4	4	3	4	4	4	3	4	4	4	0
24	M	HSG	I-II	715	124	114	127	119	124	115	114	118	124	120	5
					4	3	3	4	4	5	4	3	3	4	1
25	M	HSG	I-II	2272	129	130	132	131	132	127	126	129	131	130	2
					3	4	3	5	4	3	3	3	3	3	1
26	M	HSG	I-II	2683	117	127	122	120	126	128	126	128	122	124	4
					4	4	4	4	5	4	3	3	4	4	1
27	M	HSG	I-II	1620	123	131	128	127	131	132	129	130	127	129	3
					3	4	3	4	3	3	3	3	3	3	0
	M	HSG	I-II	31674	120	122	121	121	120	120	120	122	121	121	1
					8	9	10	9	11	10	8	8	9	9	1

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
28	M	HSG	IIIA	1319	100	95	94	97	89	93	98	95	95	95	3
					4	6	5	6	6	5	5	5	6	5	1
29	M	HSG	IIIA	1015	109	102	102	109	94	95	98	99	101	101	5
					4	6	5	5	6	6	5	5	6	5	1
30	M	HSG	IIIA	1965	103	109	99	107	98	105	107	106	100	104	4
					5	5	6	6	5	4	3	4	6	5	1
31	M	HSG	IIIA	756	117	126	124	122	129	125	120	125	123	123	4
					4	5	4	5	5	5	4	4	5	5	1
32	M	HSG	IIIA	1987	115	115	118	118	116	112	110	114	116	115	3
					4	6	5	6	6	5	4	5	5	5	1
33	M	HSG	IIIA	1309	103	98	103	98	102	101	102	101	102	101	2
					4	5	4	5	4	4	4	4	5	4	1
34	M	HSG	IIIA	3277	109	121	115	113	120	122	119	120	115	117	4
					4	5	5	5	5	4	4	4	5	5	1
35	M	HSG	IIIA	1300	111	105	111	110	106	102	103	105	110	107	4
					4	5	4	6	4	4	4	4	5	4	1
36	M	HSG	IIIA	2029	101	110	102	101	106	111	112	111	104	106	5
					4	5	4	5	4	4	4	4	5	4	1
37	M	HSG	IIIA	1533	106	108	112	102	116	113	111	112	112	110	4
					4	5	3	4	4	5	4	5	5	4	1
38	M	HSG	IIIA	3475	105	116	106	110	109	115	115	114	108	111	4
					4	4	5	5	5	5	4	5	4	5	1
	M	HSG	IIIA	19965	107	111	108	108	109	110	110	111	108	109	2
					6	9	9	8	11	10	8	9	9	9	1

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
39	M	HSG	IIIB	590	109	110	115	113	115	109	104	108	112	111	4
					4	4	4	6	6	6	4	5	5	5	1
40	M	HSG	IIIB	1634	104	119	110	111	116	118	113	116	110	113	5
					4	5	6	6	7	6	4	5	7	6	1
41	M	HSG	IIIB	2636	90	87	88	87	87	89	91	88	89	88	1
					5	5	5	5	5	6	5	5	5	5	0
42	M	HSG	IIIB	1258	103	104	106	104	108	104	103	104	108	105	2
					4	5	5	5	5	4	4	5	4	5	1
43	M	HSG	IIIB	2330	99	99	102	100	101	99	98	99	101	100	1
					5	5	5	6	5	6	4	4	5	5	1
44	M	HSG	IIIB	1060	87	90	80	90	76	87	90	85	80	85	5
					4	5	4	5	4	6	5	4	5	5	1
45	M	HSG	IIIB	1747	97	92	99	95	96	92	92	92	96	95	3
					5	5	4	6	5	6	5	5	5	5	1
46	M	HSG	IIIB	861	101	112	100	110	98	105	103	104	98	103	5
					5	4	4	5	3	5	4	4	5	4	1
47	M	HSG	IIIB	3061	92	96	89	98	85	92	92	89	87	91	4
					4	4	5	5	5	5	4	4	5	5	1
48	M	HSG	IIIB	2452	94	104	97	95	105	108	107	106	101	102	5
					4	4	4	5	5	4	3	4	5	4	1
49	M	HSG	IIIB	1680	88	96	87	89	91	99	99	95	89	93	5
					4	5	4	5	5	4	3	4	6	4	1
50	M	HSG	IIIB	3304	94	104	92	102	91	100	100	99	93	97	5
					5	5	5	6	4	5	4	5	5	5	1
51	M	HSG	IIIB	1544	91	113	96	100	104	115	112	109	98	104	8
					4	4	4	5	5	4	4	5	5	4	1
52	M	HSG	IIIB	1853	90	100	93	91	98	104	103	100	94	97	5
					4	4	5	4	4	4	4	4	5	4	0
53	M	HSG	IIIB	1216	97	111	106	100	116	117	113	113	108	109	7
					4	5	4	4	3	4	4	4	4	4	1
54	M	HSG	IIIB	1750	98	111	102	104	107	111	108	109	102	106	5
					3	4	4	4	4	3	4	5	5	4	1
	M	HSG	IIIB	28976	95	102	96	98	98	102	101	100	96	99	2
					7	10	9	8	11	10	8	10	9	9	1

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
55	M	HSG	IV	1609	89	105	95	97	102	106	101	101	95	99	5
					5	6	7	7	7	6	6	6	7	6	1
56	M	HSG	IV	1878	86	89	85	90	83	88	87	84	83	86	3
					5	6	6	6	6	6	5	5	6	6	1
57	M	HSG	IV	2050	86	97	88	92	91	97	95	93	89	92	4
					4	6	6	7	6	5	4	5	6	5	1
	M	HSG	IV	5537	87	97	89	93	92	97	94	92	89	92	3
					5	9	8	7	10	9	7	8	8	8	1
58	M	HSS	I-II	2675	118	118	119	119	117	116	117	118	119	118	1
					6	7	6	7	7	7	6	6	6	6	1
59	M	HSS	I-II	868	127	128	130	129	130	127	125	128	130	128	2
					4	5	4	5	5	5	4	4	4	4	1
60	M	HSS	I-II	584	111	107	106	109	101	103	108	107	107	107	3
					5	7	5	7	6	7	6	6	5	6	1
	M	HSS	I-II	4127	119	118	120	119	118	116	117	119	120	118	1
					7	9	9	9	10	10	7	8	8	9	1
61	M	HSS	IIIA	2349	109	113	112	111	113	113	112	113	112	112	1
					6	7	7	7	8	8	6	6	7	7	1
62	M	HSS	IIIA	960	103	101	100	102	97	99	103	101	101	101	2
					5	7	6	7	7	6	6	5	7	6	1
	M	HSS	IIIA	3309	107	110	108	109	108	109	109	110	109	109	1
					6	9	9	8	11	10	7	8	8	8	1
63	M	HSS	IIIB	1071	92	92	90	92	88	92	93	90	91	91	2
					5	7	6	7	7	6	6	6	7	6	1
64	M	HSS	IIIB	2465	98	106	102	102	105	106	105	105	103	104	3
					6	7	7	8	9	8	7	7	7	7	1
	M	HSS	IIIB	3536	96	101	98	99	100	102	101	100	99	100	2
					7	10	9	8	11	10	8	9	9	9	1

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
65	M	HSS	IV	110	89	100	94	95	98	102	99	98	95	97	4
					5	8	7	7	8	7	6	6	7	7	1
66	M	HSS	IV	61	88	89	86	90	84	85	86	86	86	87	2
					5	8	6	7	6	6	5	5	6	6	1
	M	HSS	IV	171	89	96	91	93	93	96	94	94	92	93	2
					5	10	8	8	10	11	9	8	8	8	2
67	F	HSG	I-II	1942	112	106	105	111	98	99	105	105	106	105	5
					6	6	6	6	6	6	5	5	6	6	0
68	F	HSG	I-II	1861	125	121	124	126	118	115	117	119	124	121	4
					5	7	6	7	7	7	6	6	5	6	1
69	F	HSG	I-II	1759	117	113	113	117	107	106	111	111	114	112	4
					5	6	4	7	5	6	5	5	5	5	1
70	F	HSG	I-II	464	108	96	98	102	89	90	98	96	99	97	6
					5	6	5	7	6	5	4	4	5	5	1
	F	HSG	I-II	6026	117	112	112	117	106	105	110	110	113	111	4
					8	10	10	10	11	10	8	9	10	9	1
71	F	HSG	IIIA	2262	104	100	98	104	93	95	100	98	100	99	4
					5	5	6	7	6	5	4	4	6	5	1
72	F	HSG	IIIA	1407	100	92	92	97	85	87	94	91	92	92	5
					5	6	6	6	6	5	4	4	5	5	1
73	F	HSG	IIIA	1460	108	108	106	111	103	104	106	105	108	107	2
					6	6	7	7	7	6	5	6	7	6	1
	F	HSG	IIIA	5129	104	100	99	104	94	95	100	98	100	99	4
					6	8	8	8	9	8	6	7	8	8	1
74	F	HSG	IIIB	2046	93	87	89	92	84	85	89	85	89	88	3
					6	5	7	6	7	6	5	5	7	6	1
75	F	HSG	IIIB	2029	94	97	89	99	85	91	94	90	91	92	4
					4	5	4	6	6	6	5	5	5	5	1
76	F	HSG	IIIB	1125	100	101	99	105	96	97	98	96	100	99	3
					5	6	5	7	7	7	6	6	6	6	1
	F	HSG	IIIB	5200	95	94	91	97	87	90	93	90	92	92	3
					6	8	7	8	8	7	6	7	7	7	1

Table 6 (continued)

FY86 Supply Groups Aptitude Area Averages and Standard Deviations

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
77	F	HSG	IV	100	88	90	86	95	84	87	88	84	86	87	3
					5	8	6	7	7	7	6	6	7	7	1
	F	HSG	IV	100	88	90	86	92	84	87	88	84	86	87	3
					6	8	7	7	7	7	6	6	7	7	1
78	F	HSS	I-II	408	117	110	112	117	105	103	108	108	113	110	5
					7	9	10	10	11	9	7	8	9	9	1
	F	HSS	I-II	408	117	110	112	117	105	103	108	108	113	110	5
					7	9	9	10	10	9	7	8	9	9	1
79	F	HSS	IIIA	405	105	100	100	105	95	95	100	98	102	100	4
					6	8	8	9	8	7	6	7	8	7	1
	F	HSS	IIIA	405	105	100	100	105	95	95	100	98	102	100	4
					6	8	8	9	9	7	6	7	8	7	1
80	F	HSS	IIIB	59	98	95	95	100	90	91	95	92	96	95	3
					6	9	8	8	10	7	7	8	10	8	1
	F	HSS	IIIB	59	98	96	95	100	90	92	95	92	96	95	3
					6	9	8	9	10	7	7	8	10	8	1
81	F	HSS	IV	8	93	89	90	93	86	87	89	86	89	89	3
					2	6	6	6	7	4	6	5	5	5	1
	F	HSS	IV	* 8	93	89	90	93	86	88	89	86	89	89	3
					2	6	7	6	6	4	6	5	5	5	2

Table 7

FY86 Supply Group Differentiability Statistics

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
1	M	NHS	I-II	B.G.	6	11	11	8	14	12	9	11	10	10	2
				W.G.	6	6	6	7	6	6	5	5	6	6	1
				RATIO	1.1	1.8	1.8	1.1	2.3	2.1	1.9	2.3	1.7	1.8	0.4
2	M	NHS	IIIA	B.G.	4	10	9	7	14	11	8	10	9	9	3
				W.G.	5	7	5	6	5	6	5	5	5	6	1
				RATIO	0.8	1.5	1.8	1.1	2.6	1.9	1.6	2.2	1.8	1.7	0.5
3	M	NHS	IIIB	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	6	10	8	8	11	10	8	9	9	9	2
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
4	M	NHS	IV	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	5	13	7	8	9	6	8	12	6	8	3
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
5	M	HSG	I-II	B.G.	7	9	9	8	11	10	8	8	9	9	1
				W.G.	4	4	4	5	4	4	3	3	4	4	1
				RATIO	1.9	2.1	2.6	1.7	2.4	2.5	2.3	2.5	2.2	2.2	0.3
6	M	HSG	IIIA	B.G.	6	9	9	8	12	10	8	9	8	9	2
				W.G.	4	5	5	5	5	5	4	4	5	5	0
				RATIO	1.4	1.8	2.0	1.5	2.4	2.2	1.9	2.0	1.6	1.9	0.3
7	M	HSG	IIIB	B.G.	6	9	9	8	12	10	8	9	9	9	2
				W.G.	4	5	5	5	5	5	4	5	5	5	0
				RATIO	1.5	2.0	2.1	1.5	2.5	2.0	1.9	2.1	1.8	1.9	0.3
8	M	HSG	IV	B.G.	2	8	5	4	10	9	7	9	6	7	3
				W.G.	5	6	6	7	6	6	5	5	6	6	1
				RATIO	0.4	1.3	0.8	0.5	1.5	1.6	1.4	1.6	0.9	1.1	0.5
9	M	HSS	I-II	B.G.	8	11	12	10	15	12	9	11	12	11	2
				W.G.	5	6	5	6	6	6	5	5	5	6	1
				RATIO	1.6	1.7	2.4	1.6	2.4	1.9	1.6	2.0	2.3	1.9	0.3
10	M	HSS	IIIA	B.G.	4	8	8	6	11	10	6	8	8	8	2
				W.G.	6	7	7	7	8	7	6	6	7	7	1
				RATIO	0.8	1.2	1.3	0.9	1.5	1.4	1.1	1.5	1.1	1.2	0.3

* Only one Supply Group for this subpopulation. Therefore, no between group variability or ratio.

Table 7 (continued)

FY86 Supply Group Differentiability Statistics

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
11	M	HSS	IIIB	B.G	4	10	8	7	12	10	8	11	8	9	2
				W.G.	6	7	7	8	8	7	7	7	7	7	1
				RATIO	0.8	1.4	1.3	0.9	1.5	1.4	1.3	1.6	1.2	1.3	0.3
12	M	HSS	IV	B.G.	1	8	6	4	10	12	9	8	6	7	3
				W.G.	5	8	7	7	7	7	6	6	7	6	1
				RATIO	0.1	1.0	0.9	0.5	1.4	1.8	1.7	1.5	1.0	1.1	0.6
13	F	HSG	I-II	B.G.	7	11	11	10	12	11	8	10	11	10	2
				W.G.	5	6	5	7	6	6	5	5	5	6	1
				RATIO	1.4	1.7	2.1	1.5	2.1	1.8	1.6	1.9	2.0	1.8	0.3
14	F	HSG	IIIA	B.G.	4	8	7	7	9	9	6	7	8	7	2
				W.G.	5	6	6	7	6	5	4	5	6	6	1
				RATIO	0.8	1.4	1.1	1.1	1.4	1.6	1.4	1.5	1.3	1.3	0.2
15	F	HSG	IIIB	B.G.	4	7	6	7	7	6	5	6	6	6	1
				W.G.	5	5	5	6	7	6	5	5	6	6	1
				RATIO	0.8	1.4	1.1	1.0	1.0	0.9	0.8	1.0	1.0	1.0	0.2
16	F	HSG	IV	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	6	8	7	7	7	7	6	6	7	7	1
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
17	F	HSS	I-II	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	7	9	9	10	10	9	7	8	9	9	1
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
18	F	HSS	IIIA	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	6	8	8	9	9	7	6	7	8	7	1
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
19	F	HSS	IIIB	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	6	9	8	9	10	7	7	8	10	8	1
				*RATIO	.	.	.	.	.	.	.	.	.	.	.
20	F	HSS	IV	*B.G.	.	.	.	.	.	.	.	.	.	.	.
				W.G.	2	6	7	6	6	4	6	5	5	5	2
				*RATIO	.	.	.	.	.	.	.	.	.	.	.

* Only one Supply Group for this subpopulation. Therefore, no between group variability or ratio.

Table 8

FY86 Supply Groups - % Reduction in Variability

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
1	M	NHS	I-II	POP	7	9	9	9	11	10	7	8	9	9	1
				W.G.	6	6	6	7	6	6	5	5	6	6	1
				% ch	14	33	33	22	45	40	29	38	33	32	9
2	M	NHS	IIIA	POP	6	9	8	8	11	10	7	8	8	8	1
				W.G.	5	7	5	6	5	6	5	5	5	6	1
				% ch	17	22	38	25	55	40	29	38	38	34	12
3	M	NHS	IIIB	POP	6	10	8	8	11	10	8	9	9	9	2
				W.G.	6	10	8	8	11	10	8	9	9	9	2
				% ch	0	0	0	0	0	C	0	0	0	0	0
4	M	NHS	IV	POP	5	13	7	8	9	6	8	12	6	8	3
				W.G.	5	13	7	8	9	6	8	12	6	8	3
				% ch	0	0	0	0	0	0	0	0	0	0	0
5	M	HSG	I-II	POP	8	9	10	9	11	10	8	8	9	9	1
				W.G.	4	4	4	5	4	4	3	3	4	4	1
				% ch	50	56	60	44	64	60	63	63	56	57	7
6	M	HSG	IIIA	POP	6	9	9	8	11	10	8	9	9	9	1
				W.G.	4	5	5	5	5	5	4	4	5	5	0
				% ch	33	44	44	38	55	50	50	56	44	46	8
7	M	HSG	IIIB	POP	7	10	9	8	11	10	8	10	9	9	1
				W.G.	4	5	5	5	5	5	4	5	5	5	0
				% ch	43	50	44	38	55	50	50	50	44	47	5
8	M	HSG	IV	POP	5	9	8	7	10	9	7	8	8	8	1
				W.G.	5	6	6	7	6	6	5	5	6	6	1
				% ch	0	33	25	0	40	33	29	38	25	25	15
9	M	HSS	I-II	POP	7	9	9	9	10	10	7	8	8	9	1
				W.G.	5	6	5	6	6	6	5	5	5	6	1
				% ch	29	33	44	33	40	40	29	38	38	36	5
10	M	HSS	IIIA	POP	6	9	9	8	11	10	7	8	8	8	1
				W.G.	6	7	7	7	8	7	6	6	7	7	1
				% ch	0	22	22	13	27	30	14	25	13	18	9
11	M	HSS	IIIB	POP	7	10	9	8	11	10	8	9	9	9	1
				W.G.	6	7	7	8	8	7	7	7	7	7	1
				% ch	14	30	22	0	27	30	13	22	22	20	10

Table 8 (continued)

FY86 Supply Groups - % Reduction in Variability

NO	GEND	EDUC	AFQT	TOTAL	CL	CO	EL	FA	GM	MM	OF	SC	ST	AVG	SD
12	M	HSS	IV	POP	5	10	8	8	10	11	9	8	8	8	2
				W.G.	5	8	7	7	7	7	6	6	7	6	1
				% ch	0	20	13	13	30	36	33	25	13	20	12
13	F	HSG	I-II	POP	8	10	10	10	11	10	8	9	10	9	1
				W.G.	5	6	5	7	6	6	5	5	5	6	1
				% ch	38	40	50	30	45	40	38	44	50	42	6
14	F	HSG	IIIA	POP	6	8	8	8	9	8	6	7	8	8	1
				W.G.	5	6	6	7	6	5	4	5	6	6	1
				% ch	17	25	25	13	33	38	33	29	25	26	8
15	F	HSG	IIIB	POP	6	8	7	8	8	7	6	7	7	7	1
				W.G.	5	5	5	6	7	6	5	5	6	6	1
				% ch	17	38	29	25	13	14	17	29	14	22	9
16	F	HSG	IV	POP	6	8	7	7	7	7	6	6	7	7	1
				W.G.	6	8	7	7	7	7	6	6	7	7	1
				% ch	0	0	0	0	0	0	0	0	0	0	0
17	F	HSS	I-II	POP	7	9	9	10	10	9	7	8	9	9	1
				W.G.	7	9	9	10	10	9	7	8	9	9	1
				% ch	0	0	0	0	0	0	0	0	0	0	0
18	F	HSS	IIIA	POP	6	8	8	9	9	7	6	7	8	7	1
				W.G.	6	8	8	9	9	7	6	7	8	7	1
				% ch	0	0	0	0	0	0	0	0	0	0	0
19	F	HSS	IIIB	POP	6	9	8	9	10	7	7	8	10	8	1
				W.G.	6	9	8	9	10	7	7	8	10	8	1
				% ch	0	0	0	0	0	0	0	0	0	0	0
20	F	HSS	IV	POP	2	6	7	6	6	4	6	5	5	5	2
				W.G.	2	6	7	6	6	4	6	5	5	5	2
				% ch	0	0	0	0	0	0	0	0	0	0	0

Future Research Areas

Supply group development is an area which presents multiple opportunities for additional research. Examples of areas in which additional work would be beneficial are described below.

Continuing Evaluation of Methodologies

Perform a continuing in-depth literature search and evaluation of alternative techniques. The supply group methodology is based on currently available clustering algorithms. Continuing analysis is desireable to maintain state-of-the-art awareness to insure the best possible clustering formulation.

Dynamic Evaluation of Supply

Develop of a methodology to detect changes in the supply and to determine how the corresponding supply groups should be modified. All work to date has been based on historical populations. In reality, of course, supply varies continually. Development of techniquesss which would monitor the changing flow of the supply population and automatically adjust supply groups to maintain the best performance predictions would allow EPAS to provide the optimal personjob matches.

Evaluation of Different Supply Populations

The analysis performed to date has been based on the contract population, i.e., recruits who have signed a contract to enter the Army. This population has been used for several reasons:

- It contains full information on the recruit, e.g., test scores, phsyical results, etc.
- It provides a population which the researcher can be gauranteed will need to be allocated.
- It simplifies comparisons between EPAS-based research alternatives and existing allocation methodologies.

Using this population has several limitations as well. For example, new allocation methodologies could result in enlisting personnel from the Qualified--Did not Enlist population. That is, offering an MOS better suited to the individual can be expected to increase the likelihood of the individual enlisting.

Additionally, new performance predictors may result in personnel, ineligible under previous techniques, now becoming eligible for service in some MOS.

Extensive research would be required before an expanded applicant population could be utilized. Examples of issues to be resolved include:

- o Probability of Acceptance. While some personnel in the Qualified--Did not Enlist population can be expected to enlist under revised conditions, clearly not all will. Similarly, some who previously enlisted now might not. Techniques would have to be researched and developed to predict the probability of accepting an MOS.

- o Probability of Not Qualifying. Applicants who did not sign a contract are in a "Partially Qualified" population, that is, they may not have taken all the required tests to qualify for Army service. Some of these will not qualify. To base analysis on a partially qualified population will require developing a technique for predicting qualified/not qualified.

- o Missing Test Scores. Applicants in the partially qualified population may be missing test scores necessary to predict eligibility and/or performance. Before these applicants can be used by the system, a technique will be required to fill in these missing values.

New Performance Predictors

Additional factors other than Aptitude Area Composite scores could be used to predict performance. Aptitude Area Composite scores are currently used as being the best available predictors of applicant performance. As new predictors become available, for example, as a result of the ongoing efforts of Project A, supply group formulations will be required to cluster on the new predictor.

Inclusion of new predictors will have far-reaching ramifications for EPAS. The entire system is designed to support, or is supported by, the supply group formulations. Implementation of new performance predictors will, therefore, entail significant redesign effort of most of the modules within the system. Examples of impacted areas and the redesign which would be required follow.

Data Base. The extensive data base currently in use by EPAS will have to be altered to include these new performance measures as well as the corresponding predictor test scores. Routines that access these records will have to modified.

Software will need to be developed to rebuild those portions of the data base that utilize these new fields.

Applicant Supply. Many of the issues raised when discussing the use of the partially qualified applicant population apply here as well. Supply groups will have to be redesigned to incorporate the new measures. Not the least of the required effort would entail determining how to predict test scores for a here-to-fore undefined test. Additional analyses will be needed, as well as considerable modifications made to the Quality Forecasting Module (QFM).

MOS Requirements. Training requirements will have to be either completely redefine in these new metrics or an intermediary step taken to link them to the aptitude area composites. MOS Clusters will have to be developed using these new metrics.

ACTIVE ARMY SEARCH

The Active Army Search procedure is the name used to describe the technique by which non-prior service (NPS) recruits are currently processed by the Army's Recruit Quota System (REQUEST). We reviewed the current system with two objectives in mind:

- Development of a simulation capability. A full simulation capability of the current classification methodology is being developed. This will provide us with the ability to directly compare the current system with the EPAS-enhanced system.

- Identification of interface requirements. The final deliverable required for this contract effort is an implementation plan. A thorough review of the current system is an essential prerequisite to the development of this product as it will provide the ability to identify the interface point(s) between EPAS and existing systems. (The abilility to simulate the existing system will also be used as part of this objective as it will facilitate evalutaion of what, if any, impacts will be caused by implementation of EPAS.)

In this section, we shall first discuss the eligibility standards which individuals must meet to qualify for Army service. We shall then overview the current Active Army Search algorithm and analyze some of the implications of the current methodology. Finally, we shall discuss our approach to meeting each of the two objectives.

Eligibility Standards

All applicants for the Active Army must pass specified mental, physical, and moral tests if they are to meet the minimum qualification standards. Army policy establishes the minimum levels which are to be maintained.

Basic Eligibility Requirements

The Army uses the Armed Services Vocational Aptitude Battery (ASVAB) to determine mental qualifications to enter the Army. The ASVAB includes subtests forming the Armed Forces Qualification Test (AFQT), which determines enlistment eligibility. In addition, linear combinations of the ASVAB subtests are used to generate qualifying scores in each of nine groupings, called Aptitude Areas, of Army jobs.

The Army particularly desires applicants who are high school graduates and whose AFQT scores place them in the top half of the general population. Such personnel are called quality applicants. The Army is prohibited by Congress from accepting applicants from the

bottom ten percent of the population; also, it has administratively decided against accepting applicants in the lowest AFQT quartile.

Applicant Screening and Processing

Figure 1 illustrates the steps an applicant goes through in the enlistment process. The applicant first takes the ASVAB to determine the jobs for which they qualify. They then discuss a range of potential jobs and job-specific enlistment incentives with a local recruiter.

Mentally qualified applicants then report to one of over 60 Military Enlistment Processing Stations (MEPS) for a physical examination and a careful evaluation of their high school graduation credentials. Full disclosure of any police record is also required.

After satisfying the mental, physical, and moral standards, the applicant is offered a job assignment by an Army guidance counselor and, if he/she accepts, signs an enlistment contract.

Overview of the Active Army Search Algorithm

The Active Army Search algorithm is a computerized procedure imbedded in the REQUEST System which assists the guidance counselor in the identification of job assignments for applicants. Figure 2 is a flow diagram depicting the current processing performed by the Active Army Search algorithm. The processing being performed is divided into three logical groups:

- Qualifications Checking.
- Availability Checking.
- Incentive Availability.

Qualifications Checking

The first step in the classification of recruits is the verification of their basic eligibility and the identification of skills for which they are eligible. The system first verifies that the applicant meets the minimum mental requirements for entry into the Army. These requirements are expressed as a combination of several factors. Non-high school graduates, for example, are only authorized if their AFQT scores qualify them in the upper half of the population. Females must be have AFQT scores in the upper half of the population and be high school graduates.

Determine Search Window and Qual Processing. Applicants who meet the minimum entrance requirements are checked to determine jobs (MOS) for which they are eligible. From this list of eligible jobs, the guidance counselor will display 25 options from which the applicant may select. In theory, there are on the order of 10,000 combinations

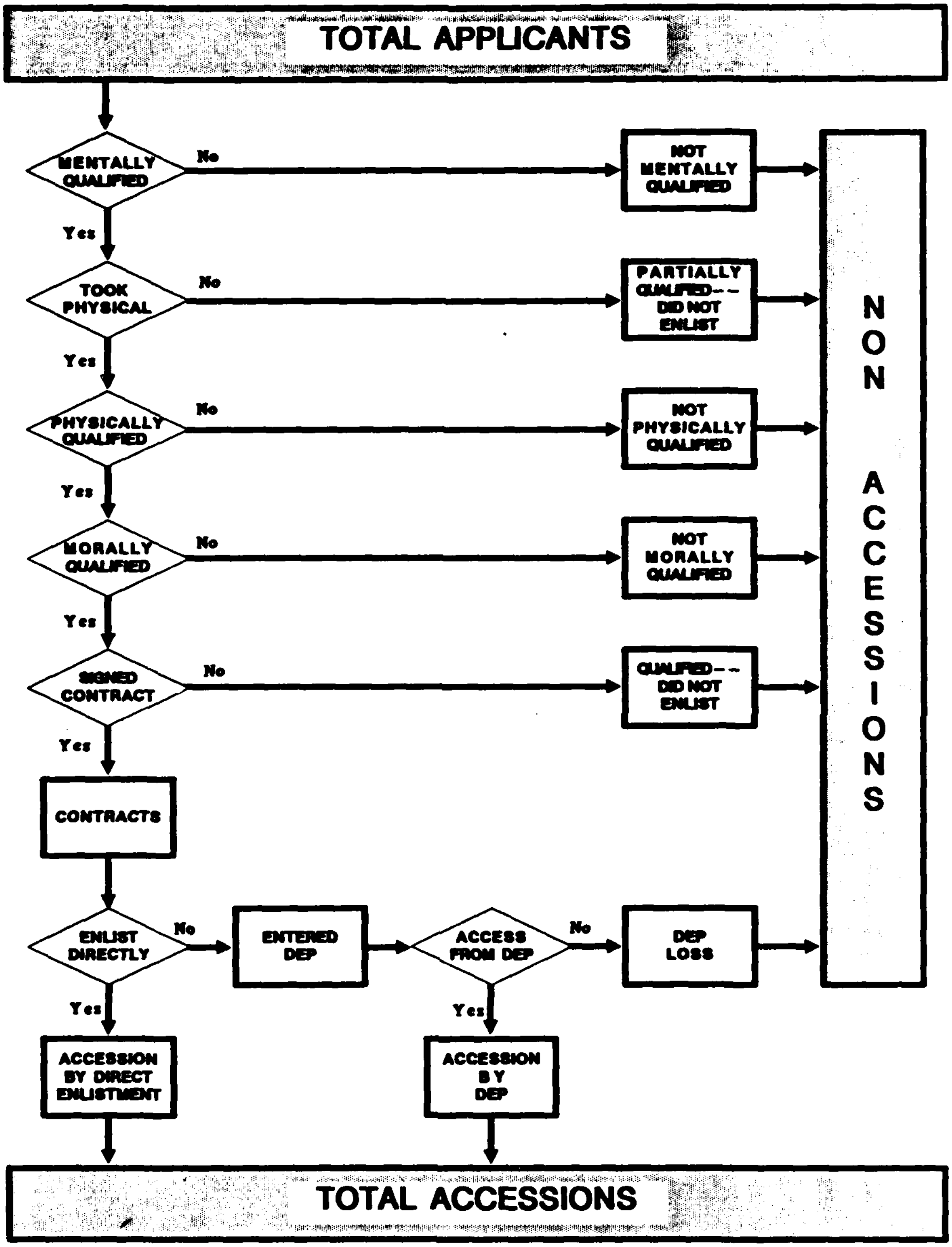

Figure 1. Army Personnel Accession Flow.

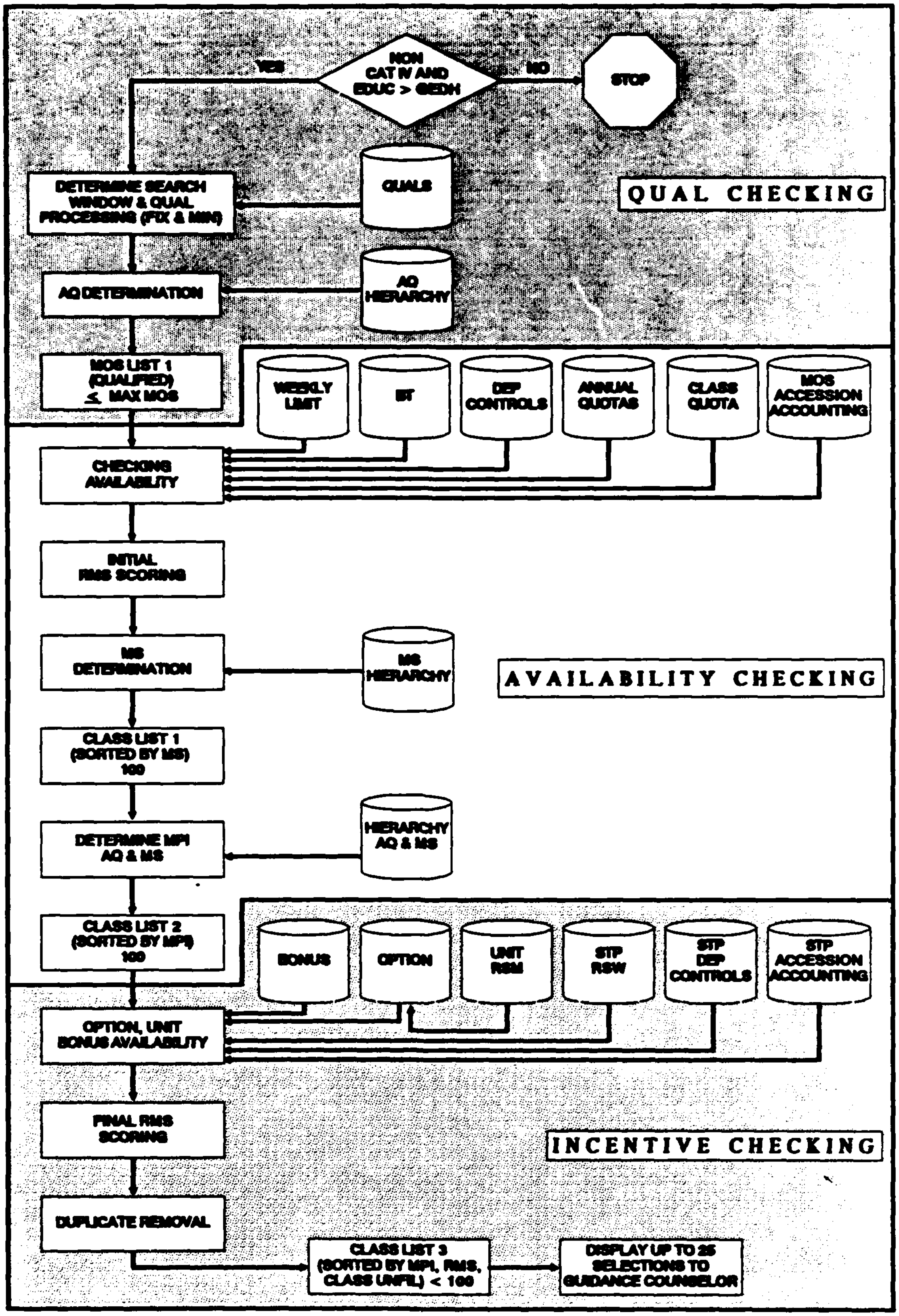

Figure 2. Active Army Search Overview.

of MOS/training-start-dates from which the 25 are selected. Several techniques are used to reduce the number of combinations to a tractable number; these are:

1. Minimum Qualifications.
2. Availability Window.
3. RUDEP and Quality Switches.

1. Minimum Qualifications. All initial entry MOS have been grouped into the nine Aptitude Areas listed in Table 1 and assigned a minimum qualification score. To be eligible for an MOS, the applicant's Aptitude Area Composite Score must be equal to or better than the qualification score for the MOS. For example, MOS 95B (Military Police), which is in aptitude area ST (Skilled Technical), has been assigned a minimum qualification score of 100. For an applicant to qualify for 95B, he or she must achieve a composite score of at least 100 in the ST area.

The first action taken by the Active Army Search algorithm is, therefore, a check of the applicant's composite scores against the qualifying score for the MOS. Only those MOS for which the applicant meets the qualifying score need be considered in the rest of the algorithms.

Additional minimum qualifications are defined for MOS based on specified demographic characteristics. For example, females are prohibited from serving in MOS which may require combat service; some MOS with highly technical requirements may require a high school diploma. Applicants are checked against these demographic qualifications to verify their basic eligibility. Again, only those MOS for which the applicant meets all the qualifications need be considered.

2. Availability Window. The minimum qualifications reduce the number of MOS to be considered for an applicant. The second aspect of the combinations--the number of training start dates--is reduced by using a windowing technique. Current Army policy allows recruits to enter the Army through the Delayed Entry Program (DEP). This program allows individuals to sign a contract, but not actually begin training until some later time.

The maximum length of the DEP is defined by current policy; the DEP length at any given point in time may, therefore, vary. To reduce the number of training dates which are considered, the Active Army Search algorithm uses a Date of Availability (DOA). A window of some predefined length--usually four or five weeks--is established from the DOA.

A second window, usually one week long, is established from the current date. This second window provides the ability to respond to any immediate requirements such as may arise from last minute losses from the DEP.

The current system considers only those MOS for which the applicant qualifies which have training dates during the windows. Figure 3 graphically depicts this process. In this figure, the circles represent training start dates within the DEP for various MOS. One of the MOS-- MOS #5--is blocked out, representing an MOS for which the applicant being processed does not qualify. All classes outside the two windows are also blocked out. Thus, the search algorithm will only process those MOS/training-start-date combinations shown in the unshaded regions.

It should be noted that the guidance counselor can directly affect the combinations being considered by moving the DOA. In Figure 3, for example, MOS #4 is shown as not being evaluated. If the guidance counselor to changed the DOA to the third week, however, it would be considered.

3. RUDEP and Quality Switches. Additional limits on the possible job assignments may be externally imposed. Two such factors are the RUDEP and the Deny Quality (DQ) switches. Both of these factors are set parametrically by personnel at the U.S. Army's Recruiting Command (USAREC) headquarters.

RUDEP establishes controls within the nominal DEP period for individual types of personnel and MOS. Up to three factors can be used to define the population groups for whom the policy is applicable. In this example, and in current policy, only two factors--education and AFQT Category--are actually used.

Table 9 provides an example of how RUDEP policy is defined. This example depicts one of several such tables which are defined on a monthly basis. It is for Non-Prior Service Males (NPSM) and is applicable only to the MOS listed at the bottom of the table. For each combination of the two factors and for each month within the maximum DEP period, a flag is defined indicating whether a job assignment is available ("X") or closed ("C") for the MOS and month combination.

A second form of external control is established through the DQ switch settings. DQ switches are used to determine whether specific MOS should be denied ("Y") or not ("N") to selected applicant types as a function of the current quality distribution within the MOS.

Each MOS has associated with it an annual goal for quality accessions, i.e., what percentage of the NPS recruits are to be high school graduate, AFQT Category I-IIIA personnel. If the percentage of the current (actual) fill is significantly higher or lower than the goal percentage, the DQ switches will be used to control the type of personnel who may be accessed into the MOS.

Table 10 depicts a segment of a summary report generated by USAREC's Recruiting Integrated Mission Management System (RIMMS). RIMMS is data base management tool developed on a Personnel Computer using the dBase III Plus Data Base Management System. Through RIMMS,

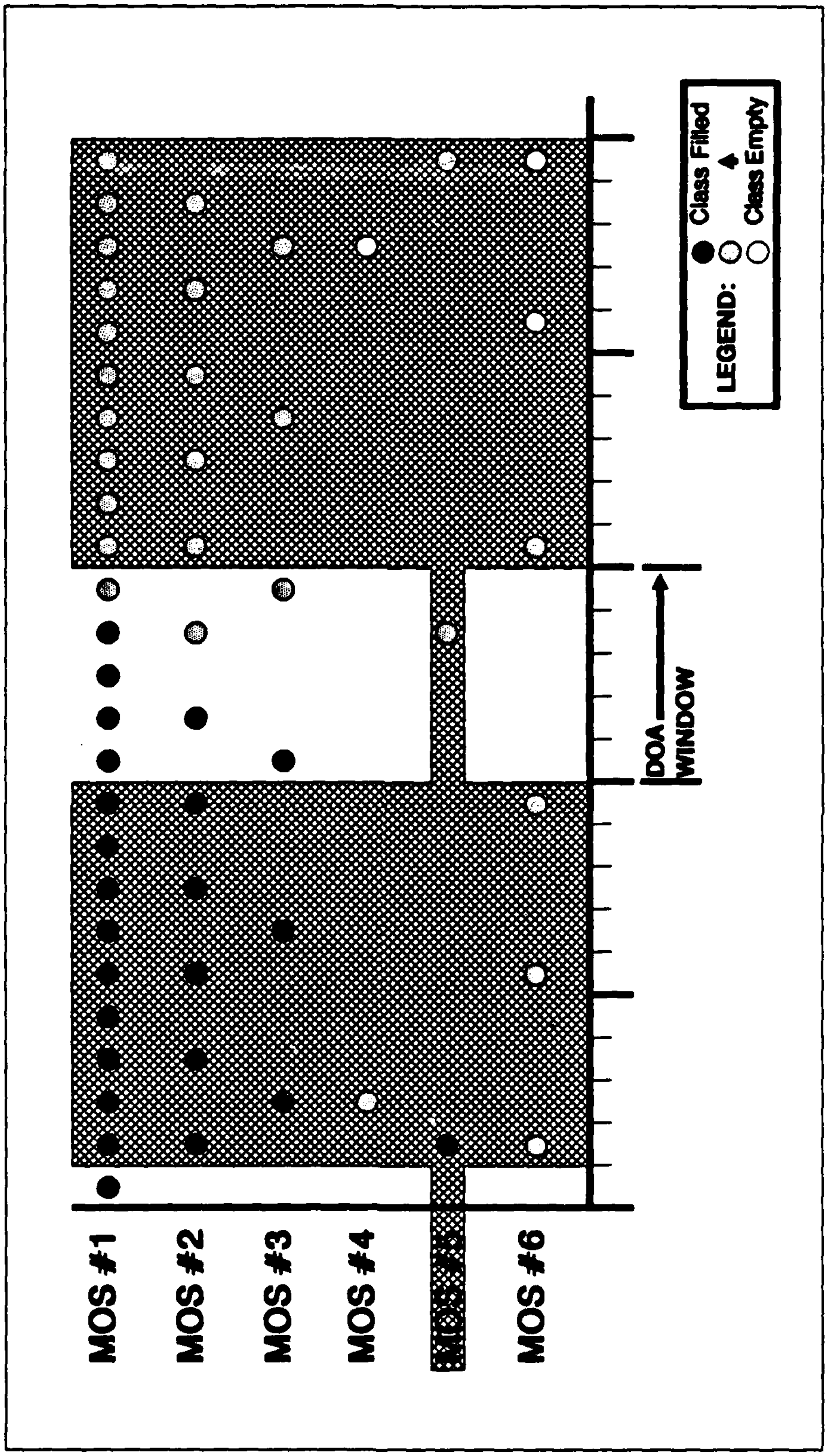

Figure 3. Date of Availability Window.

Table 9

RUDEP Control Tables

```
**** DEP CONTROL FOR TABLE  1  ****
**** NPSM
       EFFECTIVE DATE : 13/12/84
         REPORT DATE  : 13/12/84
```

FACTOR 1 EDUC	FACTOR 2 AFQT	FACTOR 3	RSM DEC 84	RSM JAN 85	RSM FEB 85	RSM MAR 85	RSM APR 85	RSM MAY 85	RSM JUN 85	RSM JUL 85
NURS-PROF	93 -99		X	X	X	X	X	C	C	C
NURS-PROF	65 -92		X	X	C	C	C	C	C	C
NURS-PROF	50 -64		X	X	C	C	C	C	C	C
NURS-PROF	31 -49		X	X	C	C	C	C	C	C
NURS-PROF	21 -30		C	X	C	C	C	C	C	C
NURS-PROF	16 -20		C	C	C	C	C	C	C	C
HSDG-ASSC	93 -99		X	X	X	X	X	C	C	C
HSDG-ASSC	65 -92		X	X	C	C	C	C	C	C
HSDG-ASSC	50 -64		X	X	C	C	C	C	C	C
HSDG-ASSC	31 -49		X	X	C	C	C	C	C	C
HSDG-ASSC	21 -30		C	X	C	C	C	C	C	C
HSDG-ASSC	16 -20		C	C	C	C	C	C	C	C
HSSR-HSSR	93 -99		X	X	X	X	X	X	X	X
HSSR-HSSR	65 -92		X	X	C	C	C	X	X	X
HSSR-HSSR	50 -64		X	X	C	C	C	X	X	X
HSSR-HSSR	31 -49		X	X	C	C	C	X	X	C
HSSR-HSSR	16 -30		C	C	C	C	C	C	C	C
COMP-ATTN	93 -99		X	X	X	X	X	C	C	C
COMP-ATTN	65 -92		X	X	C	C	C	C	C	C
COMP-ATTN	50 -64		X	X	C	C	C	C	C	C
COMP-ATTN	31 -49		X	X	C	C	C	C	C	C
COMP-ATTN	21 -30		C	X	C	C	C	C	C	C
COMP-ATTN	16 -20		C	C	C	C	C	C	C	C
NHSG-GEDH	93 -99		X	X	X	C	C	C	C	C
NHSG-GEDH	65 -92		X	X	X	C	C	C	C	C
NHSG-GEDH	50 -64		X	X	X	C	C	C	C	C
NHSG-GEDH	31 -49		C	C	C	C	C	C	C	C
NHSG-GEDH	16 -30		C	C	C	C	C	C	C	C

* * THE ABOVE DEP CONTROLS ARE IN EFFECT FOR THESE MOS ONLY:
05D1 11X1 12C1 12F1 13C1 13E1 13F1 13M1 15D1 15E1
15J1 16P1 16R1 16S1 16X1 19A1 19A3 19D1 19D3 19E1
19K1 82C1

Table 10

RIMMS Summary Report

DRO SUMMARY REPORT -- NPSM + NPSF -- DOS INCLUDED IN FILL
SOURCE:
Recruiting Integrated Mission Management System (RIMMS)

MOS	O S U T	C M F	P R I	O P E N	NPS PROG	NPS FILL	% TOT FILL	NPS TO GO	TOTAL TRNG SHORT	LOST SEATS	3A DENY	384 DENY	3A TGT %	3A FILL %	3A TO GO	384 TGT %	384 FILL %	384 TO GO
77L1	N	77	5	N	28	25	89.29	3	-3	-12	Y	Y	53	68.0	-3	47	32.0	5
81E1	N	25	7	N	76	94	123.68	-18	22	-5	Y	Y	63	80.9	-30	37	19.1	10
81Q1	N	81	3	Y	31	29	93.55	2	-1	-12	N	Y	78	89.7	-3	22	10.3	4
95B1	Y	95	2	N	4816	4662	96.80	154	177	-146	N	Y	77	79.2	-126	23	20.8	136

USAREC management personnel can track the current fills and targets for each MOS.

When the deny switch is set to "Y", personnel will be allowed into the MOS only so long as the fill percent is less than the target percent. USAREC personnel frequently monitor MOS during the day when the fill quantity is near the target quantity. When the desired quantity of fill (rather than percent) is reached, the target percent will be manually changed to a value less than the apparent fill percent. This action is necessary as the fill percent is not updated on an immediate basis, but only during specified reconciliation cycles, for example, overnight. Thus, MOS may overfill even though the deny switch has been set. The combination of setting the deny switch and artificially lowering the target percent will serve to close the MOS.

<u>Applicant Qualification Determination</u>. Once the list of MOS to be considered has been reduced, the Applicant Qualification (AQ) hierarchy score is determined. This score is intended to reflect how well an individual matches the requirements for an MOS. The AQ score is computed as the last step in the Qualifications Checking but is not actually used until later in the processing.

The hierarchy score refers to the actual scoring algorithm utilized by the Active Army Search algorithm. The hierarchy is depicted graphically in Figure 4. As is shown in the figure, the hierarchy has two principle components: the AQ and the MOS Status (MS). The AQ side of the hierarchy is further subdivided into two characteristic groupings: intelligence qualifications and physical qualifications.

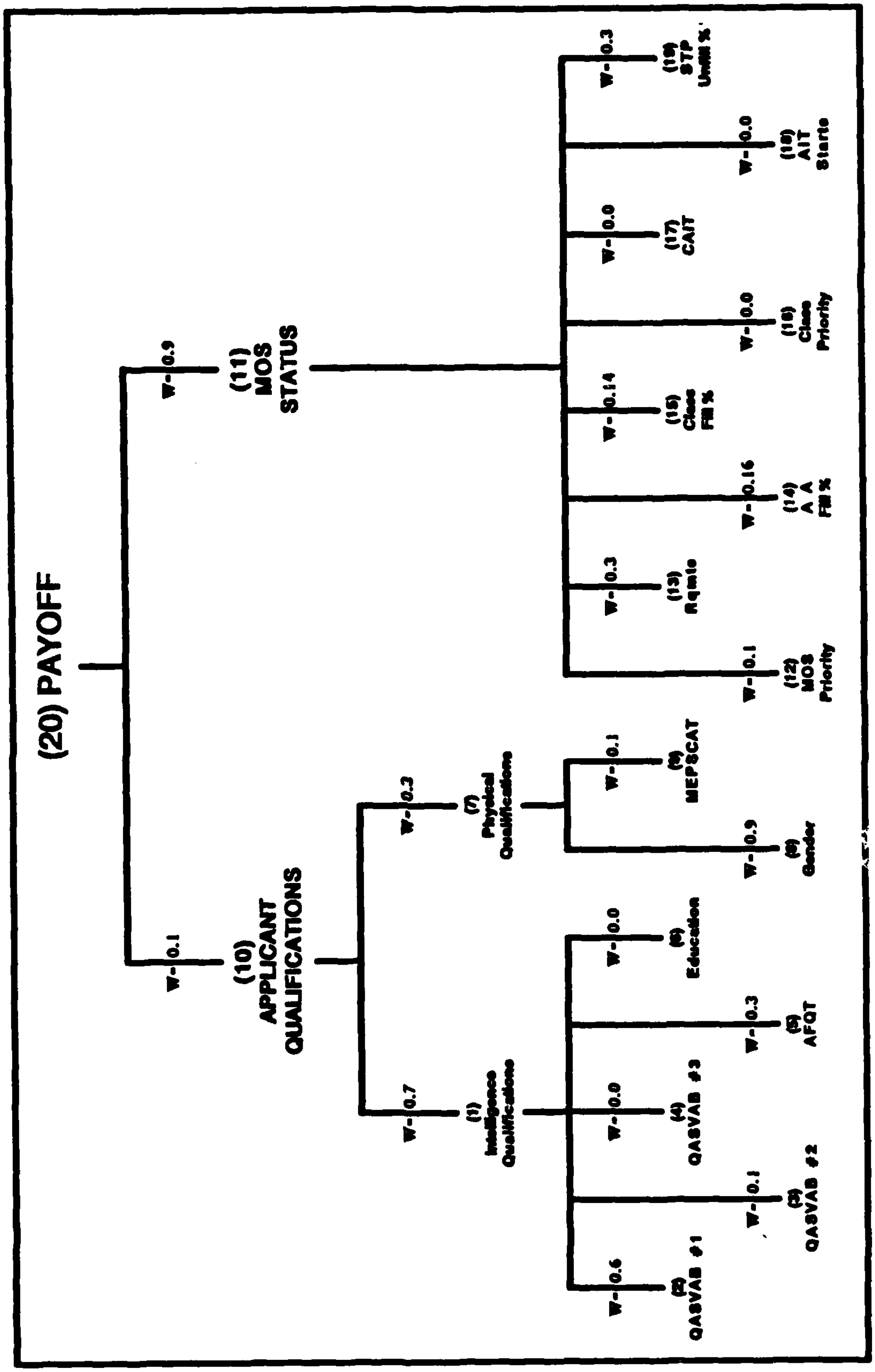

Figure 4. Scoring Hierarchy.

Each component of the hierarchy has a set of individual factors which are used to measure the applicant's suitability for an MOS. Each of the factors is transformed from its natural measure to a utility value on a scale of 0 to 1000. The resulting utility measures are linearly weighted and summed to generate the resulting payoff value associated with the person-job match.

Figure 4 shows the weighting values currently associated with each of the factors; figures 5 through 9 are the transformation functions used to generate the utility measures.

Two critical points need to be noted about the AQ factors as they are currently defined. The first is their relative weight: applicant qualifications count for only 10% ($w = 0.1$) of the total payoff value.

The second point is that, with one minor exception, none of the current transformation functions vary by MOS. (The one exception is the Aptitude Area Composite score (QASVAB). The QASVAB does have a separate transformation for MOS 26C, 26Y, 29Y, 33P, 33Q, 33R, and 33T.) The impact of this second point is that the current factors will merely introduce a constant term for virtually all MOS. This means the system does not not differentiate among the MOS. Thus, the current system is unable to determine those MOS for which the applicant is best suited.

Availability Checking

The second logical block in the search algorithm is identified as Availability Checking. This block determines whether or not the MOS/training-start-date combinations are available and assigns a relative score to each of the combinations.

Checking Availability. In this first step, the availability of training for the MOS within the selected windows is verified. The windows identify the point in time during which the applicant would be accessed into the Army--not the point at which Advanced Individual Training (AIT) for the selected MOS would begin. The factors which must be checked to determine availability include:

(1a) Basic Training (BT) availability. Traditional training sequences entail BT followed by AIT for the MOS. For MOS having the BT-AIT sequence, the system verifies that space is available in a BT class which will complete its training in time to begin the AIT class.

(1b) One Station Unit Training (OSUT). OSUT is an alternative form of training to BT-AIT. In this training, the basic military skills and the MOS skills are taught simultaneously throughout the duration of the course. For MOS with OSUT, the system checks that a class is available within the appropriate time frame.

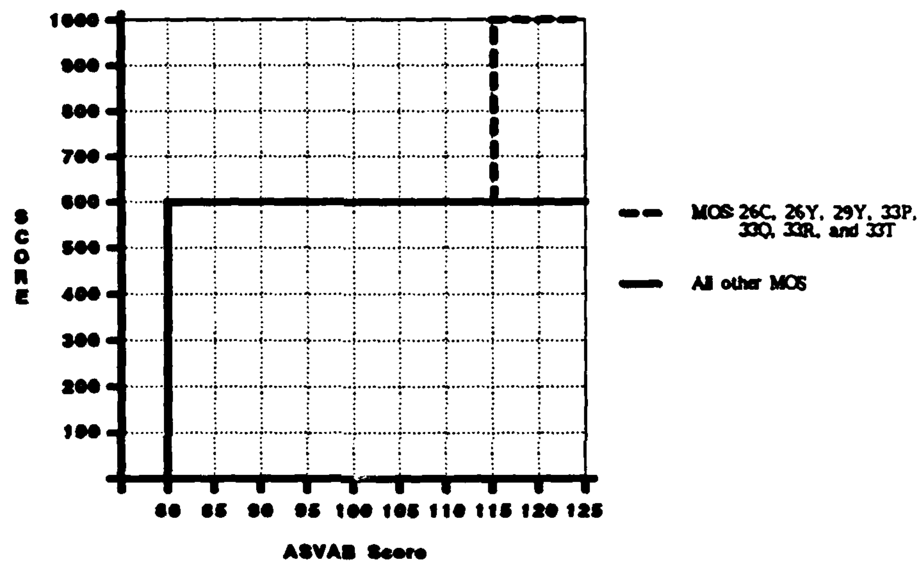

Figure 5. Aptitude Area Composite Score Transformation Function.

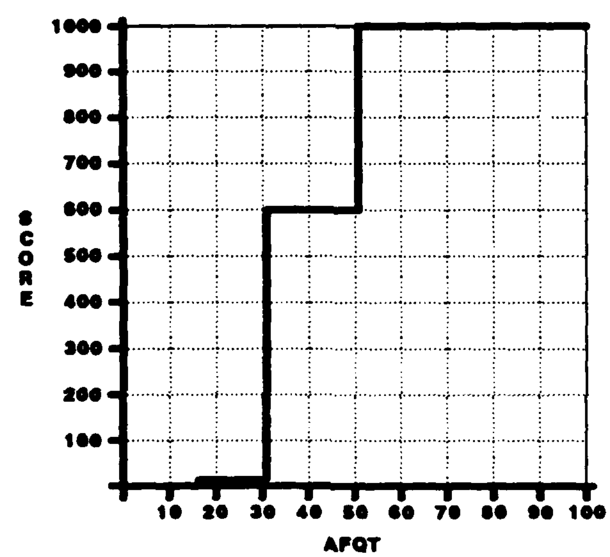

Figure 6. AFQT Transformation Function.

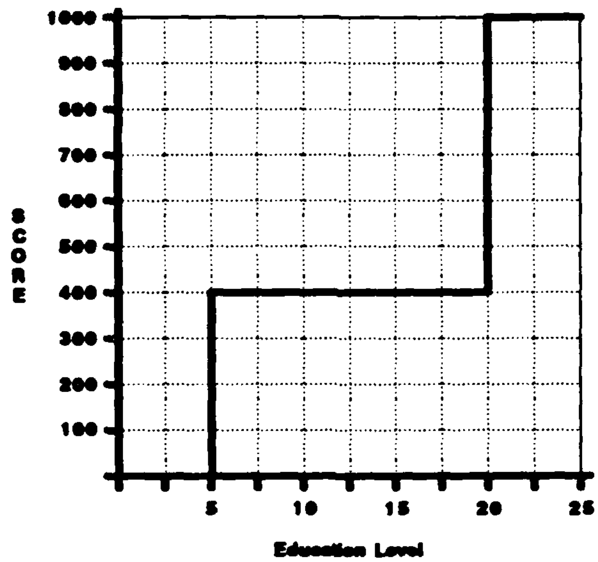

Figure 7. Education Transformation Function.

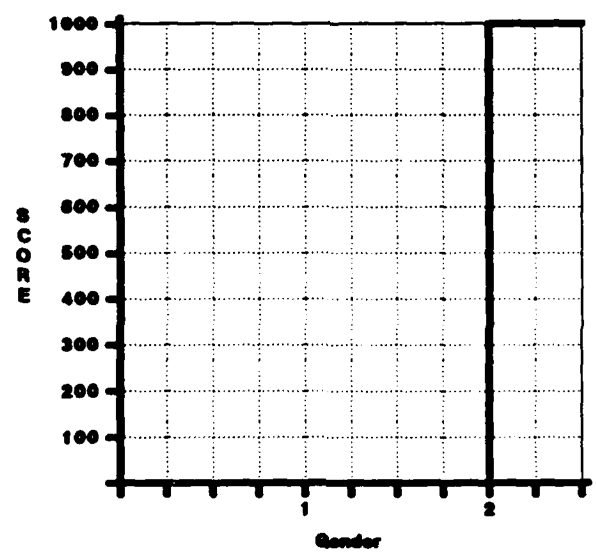

Figure 8. Gender Transformation Function.

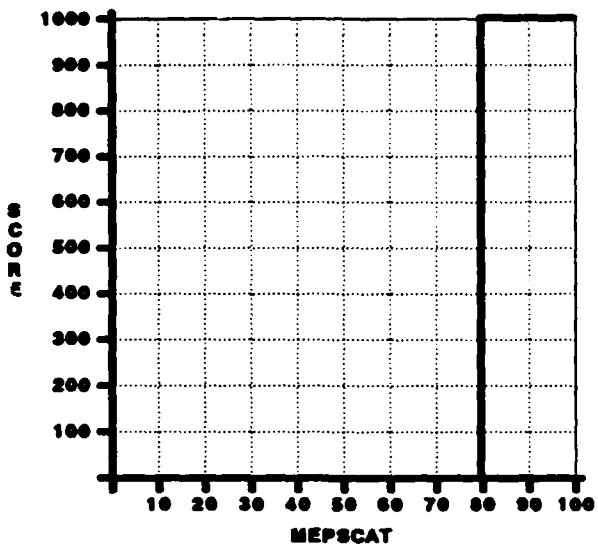

Figure 9. MEPSCAT Transformation Function.

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(2) Accession Limits. The Active Army Military Manpower Program (AAMMP) sets limits on the number of persons who may be accessed in a month. The system verifies that the applicant can be accessed at the time necessary to begin training.

(3) Annual Training Requirements. Each MOS has an annual program (AnnPro) which defines its training requirements. The system checks the MOS against the appropriate training requirement. The AnnPro is relative to the point at which the individual will complete all requisite MOS qualifications training. Thus, it is possible to have individuals being charged against the accession goal for one recruit year but against the training goal for a different year.

MOS Status Determination. Having identified the specific MOS classes to be considered, the Active Army Search algorithm next computes the MOS Status (MS) side of the payoff hierarchy. Like the AQ computations, the MS score is computed as a linear, weighted combination of factors, each of which is transformed to a 0-1000 utility measure. The weights currently used are shown in Figure 4; Figures 10-17 provide the transformation functions currently used by the MS hierarchy.

The only exception to these weights and functions is MOS 11X (Infantry). For this MOS, the MOS priority factor is assigned 100% of the MS hierarchy score. In addition, 11X is given a priority of "1" which transforms into a utility score of 1000. Thus, 11X always has the maximum score possible.

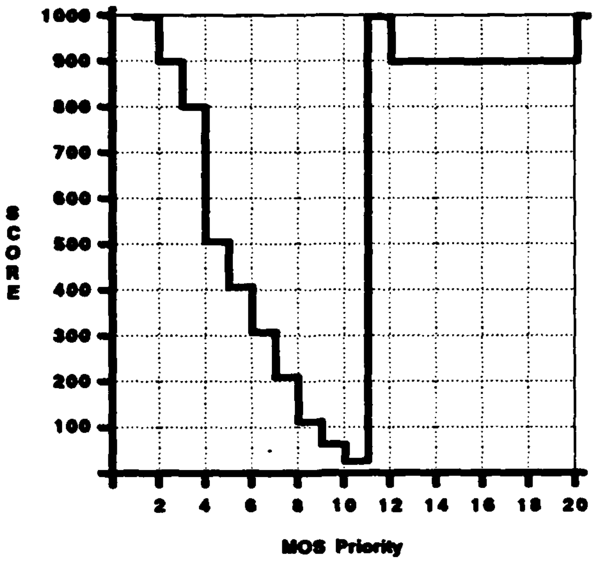

Figure 10. MOS Priority Transformation Function.

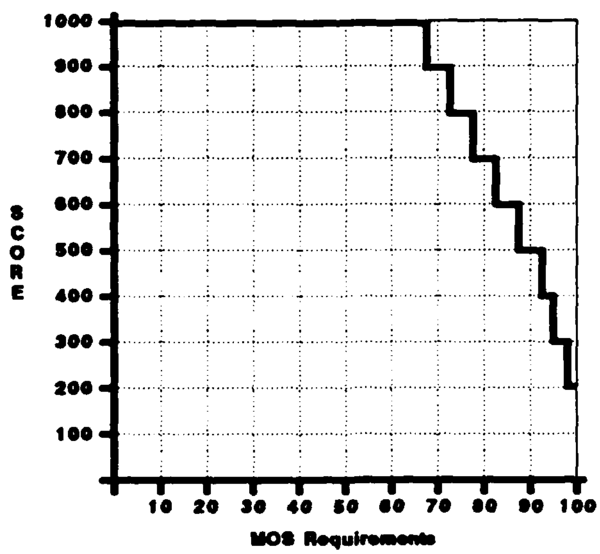

Figure 11. MOS Requirements Transformation Function.

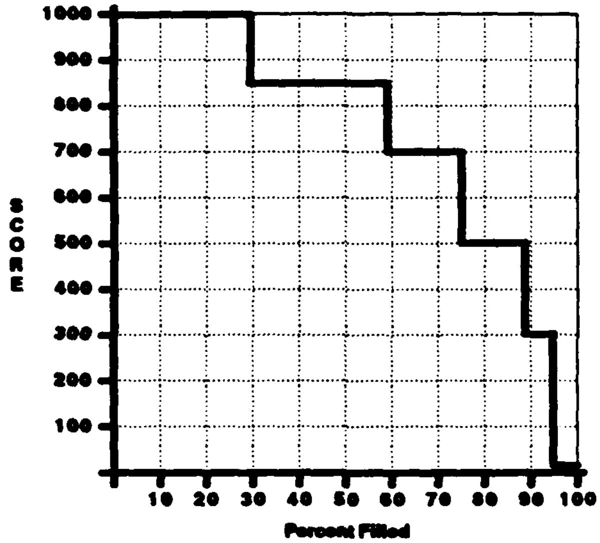

Figure 12. Active Army Fill Percent Transformation Function.

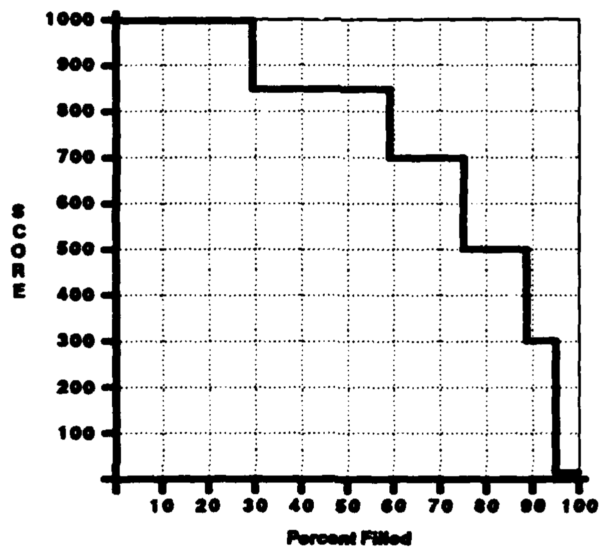

Figure 13. Class Fill Percent Transformation Function.

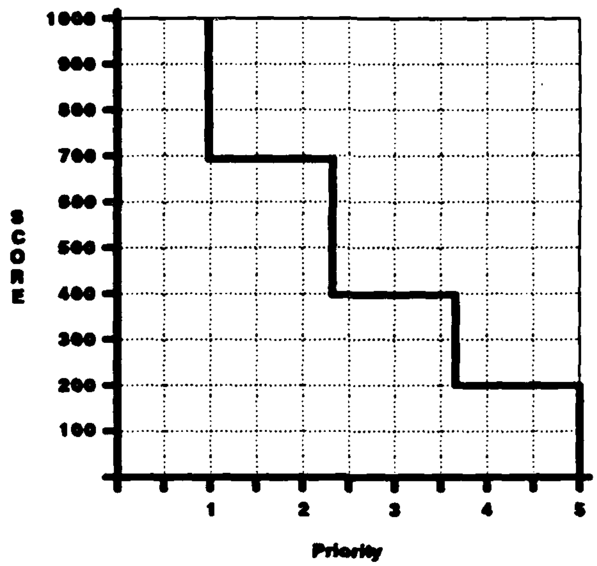

Figure 14. Class Priority Transformation Function.

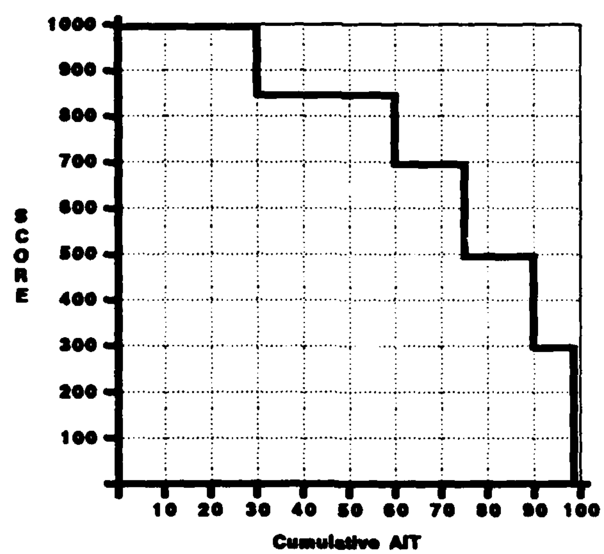

Figure 15. Cumulative AIT Transformation Function.

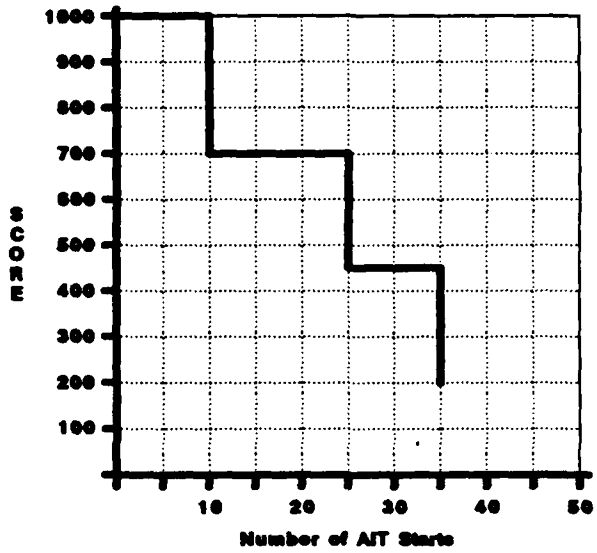

Figure 16. AIT Starts Transformation Function.

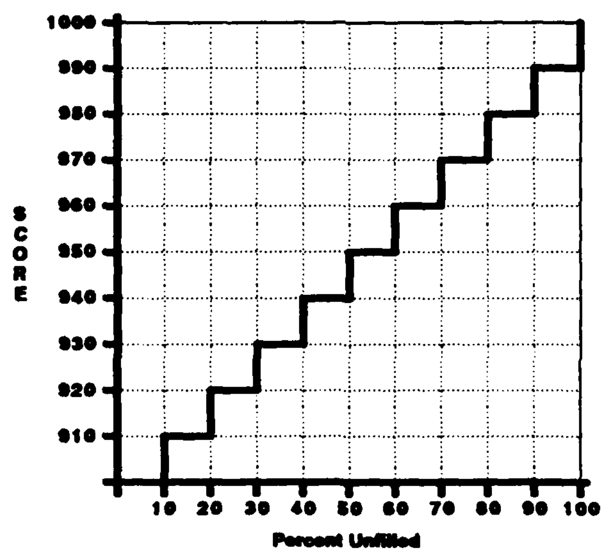

Figure 17. Special Training Program Percent Unfilled Transformation Function.

the MS hierarchy score. In addition, 11X is given a priority of "1" which transforms into a utility score of 1000. Thus, 11X always has the maximum score possible.

Sorted MOS Lists. The processing performed to this point may still result in several thousand MOS/training-start-date combinations. The next step in the Active Army Search process reduces this to a more tractable number through a sort and select process.

To do this, the identified MOS/training-start-dates are sorted into descending order based exclusively on the MS hierarchy score. The 100 highest ranking combinations are selected; all others are ignored.

The remaining 100 MOS then have the AQ hierarchy score combined with the MS hierarchy score to determine the net payoff. The MOS are then sorted again, this time using the net payoff as the sort criterion.

Incentive Checking

The third, and final, logical block in the Active Army Search algorithm is essentially a reporting device. It serves two functions: (1) identification of special enlistment options and (2) elimination of duplicates.

Enlistment Options. The Army has a variety of enlistment options at its disposal to induce applicants to accept one of the job assignments recommended by the system. Options include enlistment bonuses, the education assistance program (the Army College Fund), assignment of choice, and "buddy programs."

The system identifies which of the MOS to be recommended are eligible for one or more of the available options and will display this information at the guidance counselor's console when the list of job options is displayed.

Duplicate Removal. Some MOS have multiple start dates and classes. It is possible, therefore, for the system to generate identical MOS/report-date combinations. When this occurs, duplicates are automatically eliminated.

Job Display. The top 25 job recommendations are then displayed at the guidance counselor's console. The 25 recommendations are displayed in five screens each of which has five options. If the applicant had specifically requested an assignment which was not one of the final 25, it will be displayed as a sixth choice on the third screen.

Analysis of the Active Army Search Algorithm

The methodology currently employed has several impacts on the identification of the initial MOS assignment which leave room for improvement. Foremost among these are:

- o The Availability Window
- o The Transformation Functions
- o The Sorting Procedures

The Availability Window

The use of fixed-length windows greatly limits the ability to identify MOS which require special handling. For example, difficult-to-fill MOS, MOS which have special fill requirements (e.g., cohort), or MOS for which an applicant is particularly well suited will never be process by the system if they happen to lie outside the defined DOA window.

Highly skilled guidance counselors can ameliorate this somewhat by manually adjusting the date of availability. The system provides no assistance to the guidance counselor as he attempts to adjust the DOA.

Furthermore, the current system has no way of anticipating future arrivals of applicants. While it looks at future training seats which must be filled, it has no way of determining whether highly qualified applicants will arrive to fill the position. As a result, all MOS within the window for which the applicant is minimally qualified are treated equally.

The Transformation Functions

As was pointed out in the earlier discussion, the AQ transformation functions currently provide virtually no differentiation among MOS for any given applicant. Consider, for example, the AFQT factor. (This factor is weighted as 30% of the applicant's Intelligence Qualifications score). As shown in Figure 6, a step function generates a score based on the applicant's AFQT score. Any given applicant, however, has only a single AFQT score and, therefore, will have only a single transformed score regardless of the MOS.

The use of a single transformation function does allow differentiation among applicants, e.g., applicants with high AFQT scores will be rated higher than those with low scores. The current system, however, deals with each applicant in isolation so any differentiation which might arise from this is lost.

The design of the current system does provide the capability to distinguish among MOS. The system allows definition of separate transformation functions for every MOS; system managers do not have to use the same function for each. Here again, however, the system fails

to provide guidance to assist the manager in determining what reasonable transformation functions should be.

A related issue is the setting of the weighting factors to be used with the transformation functions. The current settings place only 10% of the final payoff on the AQ hierarchy. AFQT, for example, has a net impact of only 2% ($w_{10} x w_1 x w_5$ = 10%x70%x30%). Thus, even if the transformation functions were differentiable among MOS, the net impact of any differentiation would be minimized.

Here again, the system manager has the option of specifying weights on an MOS-by-MOS basis, providing the ability to fine tune the system to respond to different MOS as required. Again, no support is provided to assist the manager in making determinations as to what weights should be used.

One of the reasons frequently cited by Army personnel for the failure to maintain independent functions and weights for each MOS is the difficulty of determining the impact of changes. The fear exists that, if changes are made, the resulting perturbations might jeopardize reaching either the recruiting mission or the annual training requirements.

The Sorting Procedures

The final issue is that of the sorting procedures used to identify the 100 "top-ranked" MOS. This list is generated (by the process called "Class List 1" in Figure 4) by sorting the MOS / training dates within the window _totally independently of the applicant's characteristics_. Regardless of the transformation functions or weights employed, only the MS hierarchy is used to make this first cut; the AQ hierarchy is only used to reorder the selected 100. Furthermore, as was discussed earlier, the AQ transformation functions are identical for all MOS with minor exceptions. The result of the current processing, therefore, is that the identified MOS are selected solely on the Army's requirements: the applicant's interests, aptitude, and performance potential have no bearing on the list of recommend MOS presented to the guidance counselor.

The EPAS Approach

The work being performed under the EPAS contract is designed to address the specific concerns raised by the current system. This work is being performed in two areas: developing a simulation capability and interfacing between EPAS and the Active Army Search algorithm.

Simulation Capability

The development of a simulation capability will provide the Army with the ability to evaluate the probable impact of making changes to the current hierarchy factors, transformation functions, and/or weights

prior to operational implementation. This capability will become particularly important as new predictors, such as are being developed by Project A, become operational.

The new measures being developed by Project A are entirely directed at predicting applicant performance in an MOS. The current system, as we have seen, selects MOS entirely based on the requirements of the MOS. Changes will have to be made to the formulation of the current system to allow the new performance predictors to have an affect on the initial job assignment.

The simulation capability will provide the Army with the means of evaluating the new predictors with alternative formulations to ascertain the configuration which will enable improved applicant performance without impacting the Army mission.

Implementation of a simulation capability for the Active Army Search algorithm will be based on the simulation driver capabilities found for the Applicant Classification Module (ACM) of EPAS. These capabilities include the means to define a sample population, output procedures,, file update capabilities, and the system driver itself.

The actual scoring and sorting procedures utilized by the ACM differ markedly from those used by the Active Army Search algorithm and will have to be replaced by modules emulating the Active Army Search procedures. Modifications and additional capabilities which will be required include:

(1) DQ Switches. Specialized procedures are being developed to emulate the logic employed by USAREC personnel when they set the switches. These procedures, based on earlier work GRC performed using its TIMM expert system, will reset DQ switches from user-defined initial values based on data such as current fill and objective fill.

(2) DOA Window. The ACM utilizes input from the optimization procedures to determine which MOS are to be examined. This must be replace by a special procedure which will generate a DOA on which the availability window will be based. [This procedure will be based on the "final" DOA window, i.e., the one from which the job assignment is made. The procedure will not simulate a guidance counselor's shifting the DOA to encompass critical MOS.]

(3) Sort Procedures. The ACM performs only a single sort, using the net payoff of its selected MOS/training-start-date combinations. Modifications will be required in the driver to allow scoring and subsequent sorting on the MOS Status separate from the Applicant Qualifications.

(4) Hierarchy Factors. New scoring modules will be developed based on the factors and transformation functions used by the current system.

(5) System Driver. The ACM is driven primarily by input from the optimization procedures--input which is not utilized by the current system. Modifications will be required to the driver to enable it to respond to time-oriented events (such as resetting DQ switches at the end of a day).

EPAS Interface

The primary objective of this analysis is, of course, to identify the best means by which the optimal guidance generated by EPAS can be communicated to, and utilized by, the Active Army Search algorithm. As indicated by the preceding discussions, significant differences exist between the methodology employed by EPAS (which is driven primarily by the optimization procedures) and the current Active Army Search (which is driven primarily by the immediate Army MOS requirements).

Figure 18 depicts a search algorithm which, while essentially the Active Army Search procedure as it now exists, has been modified to accept the optimal guidance being generated by EPAS. There are two primary areas where differences occur, as described below.

Quality Checking. The modification here is the elimination of the DOA-based search window. In its place is direct input from the EPAS optimization procedure providing a preferred list of MOS/training-start-date combinations. EPAS generates different preferred lists based on the characteristics of the applicants, the needs of the Army (both current and projected), and projected applicant supply. Thus, the use of the EPAS generated lists will identify MOS / training dates which simultaneously address the applicants abilities and the Army's needs.

Using the EPAS ordered list to define the MOS/training-start-date combinations will significantly alter the MOS which are processed by the search algorithm. These changes will be reflected in three ways:

- There is no aritificial time window imposed on any MOS. Any open training date within the full DEP horizon may be recommended by the optimization procedures.
- Not all MOS (for which the applicant is eligible) will be recommended for a specific date. The DOA window treats all eligible MOS within the window equally; the EPAS ordered list will only identify MOS which have a high priority.
- Different lists will be generated for applicants from different mission blocks. The current system looks at all MOS for which the applicant is minimally qualified within the arbitrarilly-defined window; EPAS looks at all MOS for which the applicant is best qualified within the entire DEP horizon. Thus, individuals with different aptitudes will receive different ordered lists.

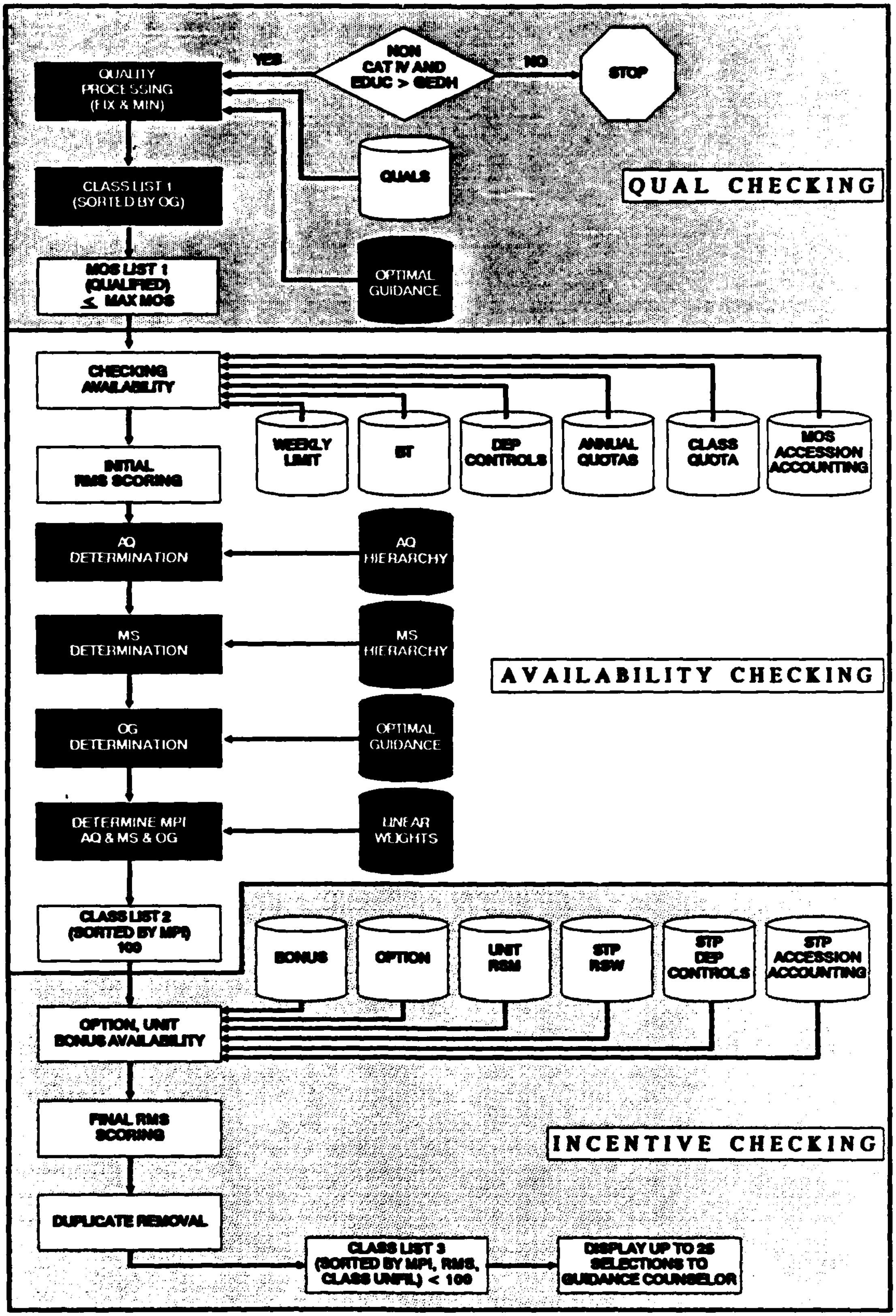

Figure 18. Modified Search Algorithm.

- The first sort is done by the EPAS optimization routines based on the relative importance of the Optimal Guidance (OG). Recall that this guidance includes Army requirements and MOS priority as well as applicant characteristics.

Availability Checking. The significant changes within the Availability Checking block are in the formulation of the net payoff and the sort procedure. The obvious change in the net payoff is the inclusion of a third branch in the hierarchy tree: Optimal Guidance (OG) determination.

In addition to ordering the recommendations, the OG provides information on the relative importance of the recommendations on the EPAS ordered list. This enables the model to identify "critical" assignments, i.e., MOS/training-start-dates which need to be filled to ensure the annual program and/or the mission goals are achieved.

The second change to note is the elimination of the sort based solely on the MS hierarchy. The initial sort would be performed by the optimization routines. Any reduction in the number of MOS/training-start-dates to be considered would be made from the EPAS list.

The final area in which changes would be made is in the transformation functions and linear weights. The work being performed by Project A will result in new factors to predict an applicant's performance in the Army, in general, and in individual MOS, in particular. Inclusion of this effort will clearly require changes to the transformation functions to include the new predictors.

Perhaps not as clear are changes that will also have to be made to the linear weights if the efforts of both Project A and EPAS are to be effective. The current weighting scheme (90% on the MS hierarchy) effectively eliminates any significant contribution from other factors. A better balance between the AQ and MS hierarchies will be required if the Project A (i.e., new AQ) factors are to be used. If this is done, increased significance will be placed on the EPAS (i.e., OG factors) to ensure that the Army's goals and objectives will continue to be met.

PROGRESS SINCE LAST REPORTING PERIOD

This section discusses the work that has been performed in support of the development of EPAS since the last reporting period, encompassing April 1988. The subsections that follow present project research, problems encountered, products, and reports, meetings and financial information.

Project Activities

Task 4.1: NPS EPAS DEVELOPMENT

Transference of EPAS to ISC-P. Verification of the feasibility of transfering EPAS, Version 3, to the U.S. Army Information System Command-Pentagon (ISC-P) Computer Facility has been initiated. This will be a direct transfer from the National Institute of Health (NIH) Computer Facility, i.e., no code conversion would be performed.

Data Base Development/Analysis. The EPAS VSAM data base has been copied to ISC-P Computer Facility.

Task 4.2: COST-BENEFIT ANALYSIS

The Cost-Benefit Analysis has been completed and delivered to ARI. A review of the analysis was held May 21, 1986.

Task 4.3: ENLISTED RETRAINEE ADDITION TO NPS EPAS

No activities for this reporting period.

Task 4.4: MMM COMPARISON WITH EPAS

Analysis of the Army's current NPS classification routines (i.e., REQUEST MOS Search Algorithm) continues. Analysis on the data currently used by REQUEST continued to identify the similarities and differences between the two systems and determine the best means for interfacing the two systems.

Design of the MMM simulation module was begun. When this module is completed, it will allow direct comparison of the MMM and EPAS results.

Task 4.5: EPAS SUPPORTED ANALYSES

Analysis was conducted during this reporting period to evaluate the affects of the weights and transformations employed by MMM. Results were compared to the results which would be obtained were the existing system enhanced by EPAS' optimal guidance.

Task 4.6: EPAS REFINEMENTS

Desireable EPAS refinements are being documented based on an analysis of the requirements for an operational field test.

Task 4.7: DOCUMENTATION OF EPAS

No activities this period.

Problems Encoundered or Anticipated

This contract needs to be extended to coincide with completion of Project A. This action is necessary to support two contract activities, specifically:

- o Supporting Project A analyses.
- o Implementation of Project A performance predictors.

A contract modification is necessary to convert EPAS to operate according to the standards established by the ISC-P computer facility. This will entail conversions to the user interface, data base management routines, and external data access capabilities.

Project Products Produced

No activities for this reporting period.

Project Reports Produced

No activities for this reporting period.

Summary of Briefings, Meetings, Visits, or Seminars

16 March 1988 - Meeting at Fort Sheridan, IL to present EPAS status to USAREC personnel. Participants were LTC Wayne Easley, USAREC; Mr. Edward J. Schmitz and Roy Nord, ARI; and Mr. Frank Konieczny and George Brown, GRC.

Task 4.5: EPAS SUPPORTED ANALYSES

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Desireable EPAS refinements are being documented based on an analysis of the requirements for an operational field test.

Task 4.7: DOCUMENTATION OF EPAS

No activities this period.

Problems Encoundered or Anticipated

This contract needs to be extended to coincide with completion of Project A. This action is necessary to support two contract activities, specifically:

- Supporting Project A analyses.
- Implementation of Project A performance predictors.

A contract modification is necessary to convert EPAS to operate according to the standards established by the ISC-P computer facility. This will entail conversions to the user interface, data base management routines, and external data access capabilities.

Project Products Produced

No activities for this reporting period.

Project Reports Produced

No activities for this reporting period.

Summary of Briefings, Meetings, Visits, or Seminars

16 March 1988 - Meeting at Fort Sheridan, IL to present EPAS status to USAREC personnel. Participants were LTC Wayne Easley, USAREC; Mr. Edward J. Schmitz and Roy Nord, ARI; and Mr. Frank Konieczny and George Brown, GRC.

19 March 1988 - Meeting at GRC to discuss EPAS progress during the last month. Participants were Mr. Edward J. Schmitz, ARI; LTC D. Michaels and CPT R. Basinger, SFFFDO; Mr. Charles Smith, Henry Weigel, Frank Konieczny, and George Brown, GRC.

Professional Person-Months

(Based on 160 person-hours per month.)

March	Total to Date	Remaining in Current Increment
4.43	443.42	14.5

Funds Expended (Exclusive of Fee)

(Based on GRC FY 1988 provisional indirect rates)

March	Total to Date	Remaining in Funding Increment	Remaining in Contract
$36,035	$3,834,425	$116,564	$187,517

Professional Person-Hours Worked

STAFF	TASK	PERSON-HOURS
Mr. Weigel	4	3.5
Mr. Brown	4	144.5
Mr. Konieczny	4	17.5
Mr. Hutton	4	181.0
Mr. Hudson	4	167.0
Mr. Stewart	4	195.5
Total Person Hours		709.0

Technical Support

No technical support activities this month.

Computer and Data Base Activities

Computer-related activities this month consisted of data storage and processing in support of the MMM analyses at the National Institute of Health Computer Facility. Costs for these activities totaled $16,770.70.